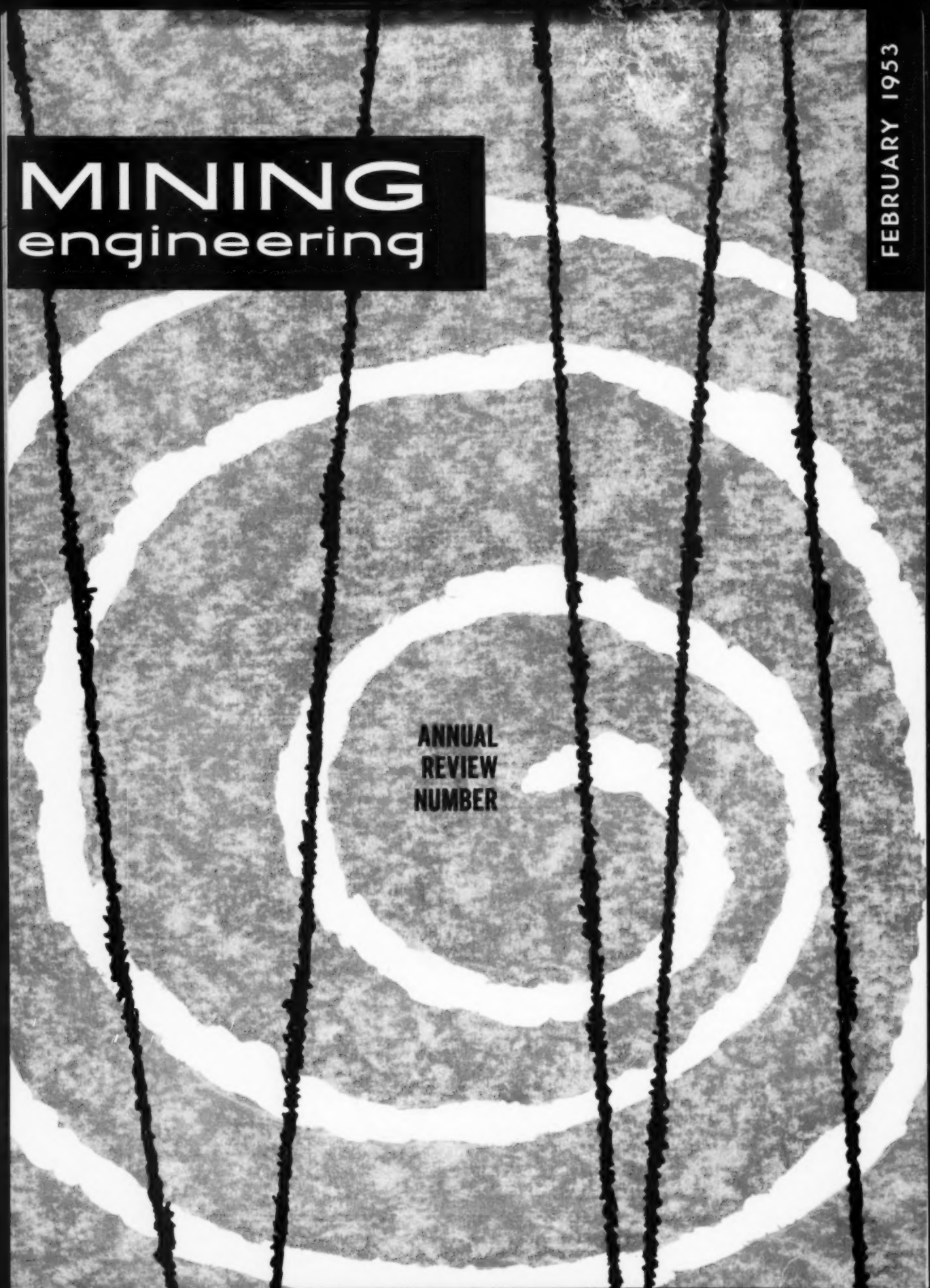
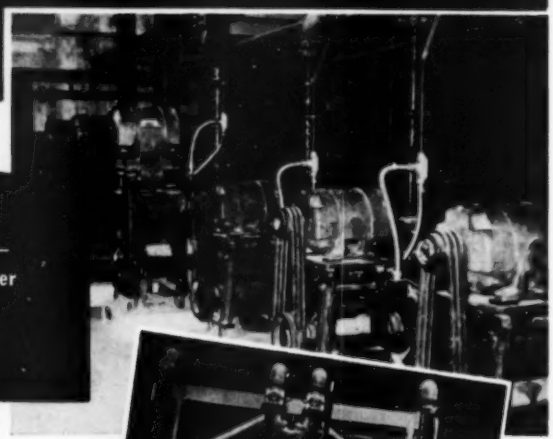

MINING
engineering
FEBRUARY 1953
ANNUAL
REVIEW
NUMBER

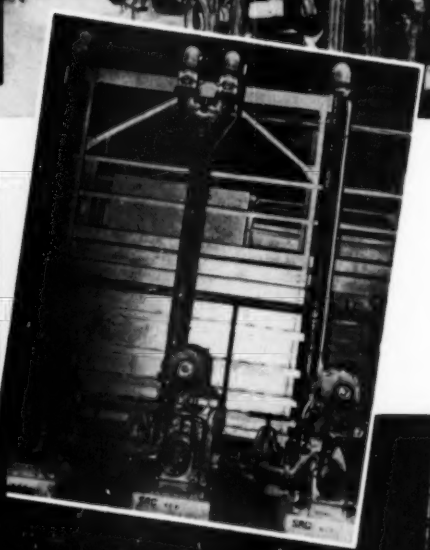
WILFLEY *Sand* PUMPS

In the World's Greatest Open Pit Copper Mine and Sulphide Plant at Chuquicamata, Chile

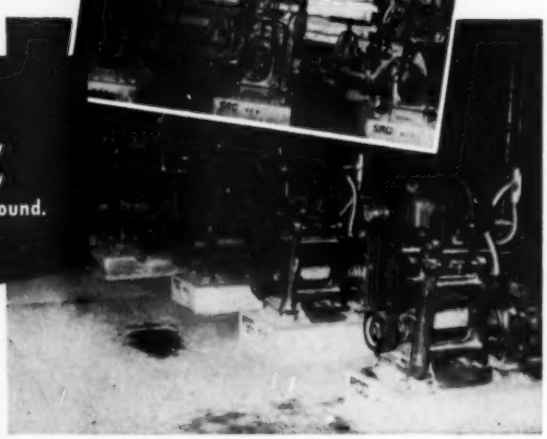
Wilfley Sand Pumps **are an integral part of the huge operation carried on in the fabulous new $100,000,000 plant at Chuquicamata, Chile. Day and night dependable Wilfley's deliver continuous, trouble-free performance . . . playing a major role in the dramatic success of this great mining enterprise.**



Primary Rougher Overflow Pumps—Secondary Rougher Overflow Pumps in background.



Secondary Cleaner Tails Pumps—Secondary Cleaner Overflow Pumps in background.



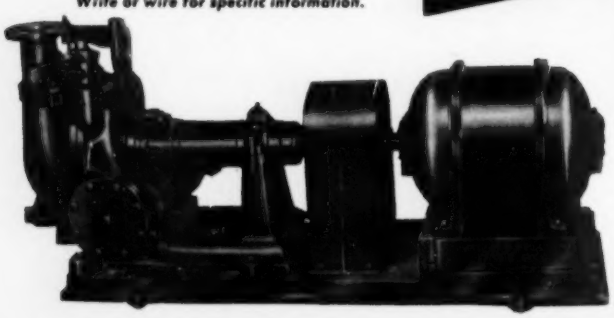
Final Concentrate Pump—Secondary Rougher Overflow Pumps in background.

New Model "K"

WILFLEY *Sand* PUMP

The new Model "K" Wilfley Sand Pump answers the 3 important economic considerations in the handling of solids: **1.** High Operating Efficiency—the Model "K" features important mechanical improvements which give you substantial dollar savings in power and production costs. **2.** Low Maintenance Cost—Wilfley's precision engineering assures dependable operation with a minimum replacement of parts. **3.** Minimum Installation Expense—the Model "K" is specially designed for simple installation, saving plant operator's time, trouble and added expense.

Write or wire for specific information.



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New York Office: 1775 Broadway, New York City, U.S.A.

MINING engineering

VOL. 5 NO. 2 FEBRUARY, 1953

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— Personnel Service —

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service, Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Mining Engineer, 39; experienced production engineering and research in mineral and construction industries. Able and willing to undertake difficult assignment, U. S. or Latin America. M-9.

Mining Engineer, graduate, 29, married, veteran. Three years responsible operating experience all phases open-pit mining; screening plants, hydraulics, earth moving, draglines. Available reasonable notice. Will consider foreign or U. S. M-10.

Mining Engineer, 38, E.M., M.S. Married, family of four. Experienced coal drilling, development and property mapping, underground mechanization, preparation plants and surface layout. Employed. Registered Professional Engineer. Available short notice. M-11.

Mine Superintendent, 49, married. Twenty-six years experience surface and underground operation and development in western U.S.A., Canada and Philippines. Know all phases mining except coal or milling. Working knowledge Spanish. Available immediately, any location with wife, a registered nurse. M-4-412-E-8-San Francisco.

POSITIONS OPEN

General Superintendent, 35 to 50, college graduate preferred. Must have ten years experience in open-pit iron ore mining, underground iron ore mining, and knowledge of iron ore beneficiation. Duties will be to supervise and coordinate activities of superintendents and department heads. Will be active in the field. Must have car. Salary, $7200 to $10,800 year. Location, Minnesota. T9439.

Mining Engineer, graduate, with experience in underground operations for a fluorspar mine. Salary open depending on experience. Location, western United States. Y7724.

General Manager with technical education and experience and executive ability to assume complete responsibility in operating a plant doing stripping, mining, hauling, milling, drilling and delivery of manganese ore. Location, Arkansas. Y8066.

Kiln Superintendent to take charge of the calcining and modulizing section of a manganese plant designed to produce 500 tons per day of metallurgical grade nodules. Will take charge of a crew of about 25 men. Location, Nevada. Y8069.

Engineers. (a) Mill Superintendent with minimum of five to ten years' experience in mill for metal mining company. (b) Assistant Mining Engineers, for metal mining operations in the Philippine Islands. Salaries open. Y5022.

Recent Graduate in mining, to handle surveying, mapping, geology and the laboratory for new manganese mine and mill in Virginia. Y6985.

WANTED: EXPERIENCED MINING ENGINEER. For Exploration, Evaluation and Operations. Man required for both domestic and overseas work. Job may require residence abroad. Excellent opportunity.

Box B-3 MINING ENGINEERING

Mineral Economist, 25, married. Two and one-half years' experience in research on coal problems. Work has shown progressive increase in responsibility. Excellent Report Writer. Presently employed. Available on short notice. Will consider any location.

Box B-4 MINING ENGINEERING

Experienced graduate metallurgists and metallurgical engineers required for large research and development organization in Northern Rhodesia. Duties relate to process metallurgy of copper, cobalt, lead, zinc and other base metals, with emphasis on ore concentration by flotation. Applicant must have minimum 5 years' industrial experience. Total remuneration, £2,000 to £2,500 according to qualifications and experience, comprises basic salary, variable metal bonus and cost of living allowance. Generous pension and leave privileges. Housing provided at nominal rental. Free transportation to Northern Rhodesia for successful applicant and immediate family. Applications stating age, marital status, qualifications, experience record, availability, and accompanied by a recent photograph should be addressed to The Secretary, P. O. Box 172, Kitwe, Northern Rhodesia.

Engineers. (a) Mining Engineer-Geologist, for service in Brazil in connection with carrying out a program for procurement of mica, beryl, tantalite-columbite and other minerals. Should be familiar with the mining and classification of mica and other pegmatite minerals. Qualified to appraise possibilities for initiating or expanding small mining operations for these minerals. Will be required to do mostly field work. Salary, $9130 to $11,020 a year plus a maximum quarter's allowance of $2800 to $3500 a year and a post allowance of $240 to $330 a year. Per diem expenses are also granted while away from headquarters on official business. Dependent may accompany the employee. (b) Mining Engineer-Geologist in Mexico City for work including field examinations and evaluations of projects relating to the exploration, development, expansion of production or procurement of various strategic metals and minerals in Mexico and other Central American areas. Salary to start, $9130 plus allowances. Y8057.

MINING or MECHANICAL ENGINEER to assist in export sales of mining and earth moving equipment. Knowledge of foreign languages helpful. Location New York City. State salary desired.

Box B-2 MINING ENGINEERING

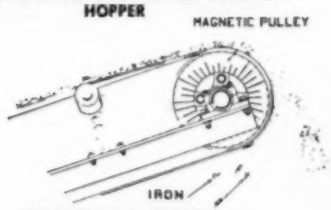
POSITIONS AVAILABLE

The Bureau of Mines is recruiting mining engineers, metallurgists, and fuel technologists, to serve abroad on mining projects conducted under the Point Four and other foreign programs. Salaries range from $5,000 to $9,000 per annum, depending on the qualifications of the applicant, the responsibilities of the assignment, and the area in which the work is done. There are also rental, and in some areas other allowances to compensate for unusual conditions encountered abroad. Some short-term assignments are available from time to time but most of the positions carry a minimum two-year tenure of office. Travel expenses for the employee are paid under all circumstances and for the longer-term assignments travelling expenses for family and transportation of a limited quantity of household goods are provided. United States citizenship and security clearance are mandatory for applicants, and United States citizenship for wives who accompany their husbands abroad also is required. Applicants must be physically capable of performing rugged work in the field. Additional information can be obtained upon application to the office of the Regional Director, Region IX (Foreign Minerals), Bureau of Mines, Washington 25, D. C.

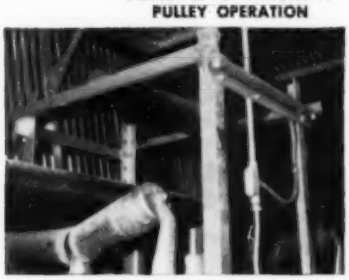
TRAMP IRON can't beat the Brains Brawn of this DINGS Iron Detector Magnetic Pulley Team

In this ore preparation plant—Quick acting Dings electronic Iron Detector checks main belt burden for large, unwieldy iron rods, rails, chunks—stops belt instantly for their removal. Then Dings Magnetic Pulleys take over the crusher protection job.

DINGS ELECTRO-PULLEY OVER CRUSHER HOPPER



PRINCIPLE OF MAGNETIC PULLEY OPERATION



DINGS IRON DETECTOR

POWERFUL DINGS ELECTRO-PULLEYS . . . give fully automatic iron removal—have virtually unlimited life when given minimum attention. These units have the extra depth of magnetic field, required for heavier belt burdens—but cost very little to operate.

Installation as head pulleys in conveyor systems is usually simple—the Dings pulley shaft is machined to the dimensions of that of the pulley being replaced and the same bearings are used. Little wiring is required.

Dings air-cooled design provides cooler, more economical operation and longer life. Separate section construction plus bronze coil covers make possible the most efficient distribution, greatest penetration of magnetic field. And Dings coil winding process virtually eliminates the possibility of electrical breakdown. Get capacities and dimensions in Catalog C-1001-A.

Alone or in combination Dings Magnets are your best protection against tramp iron—for a look at the complete Dings line send for Catalog C-5000-B.

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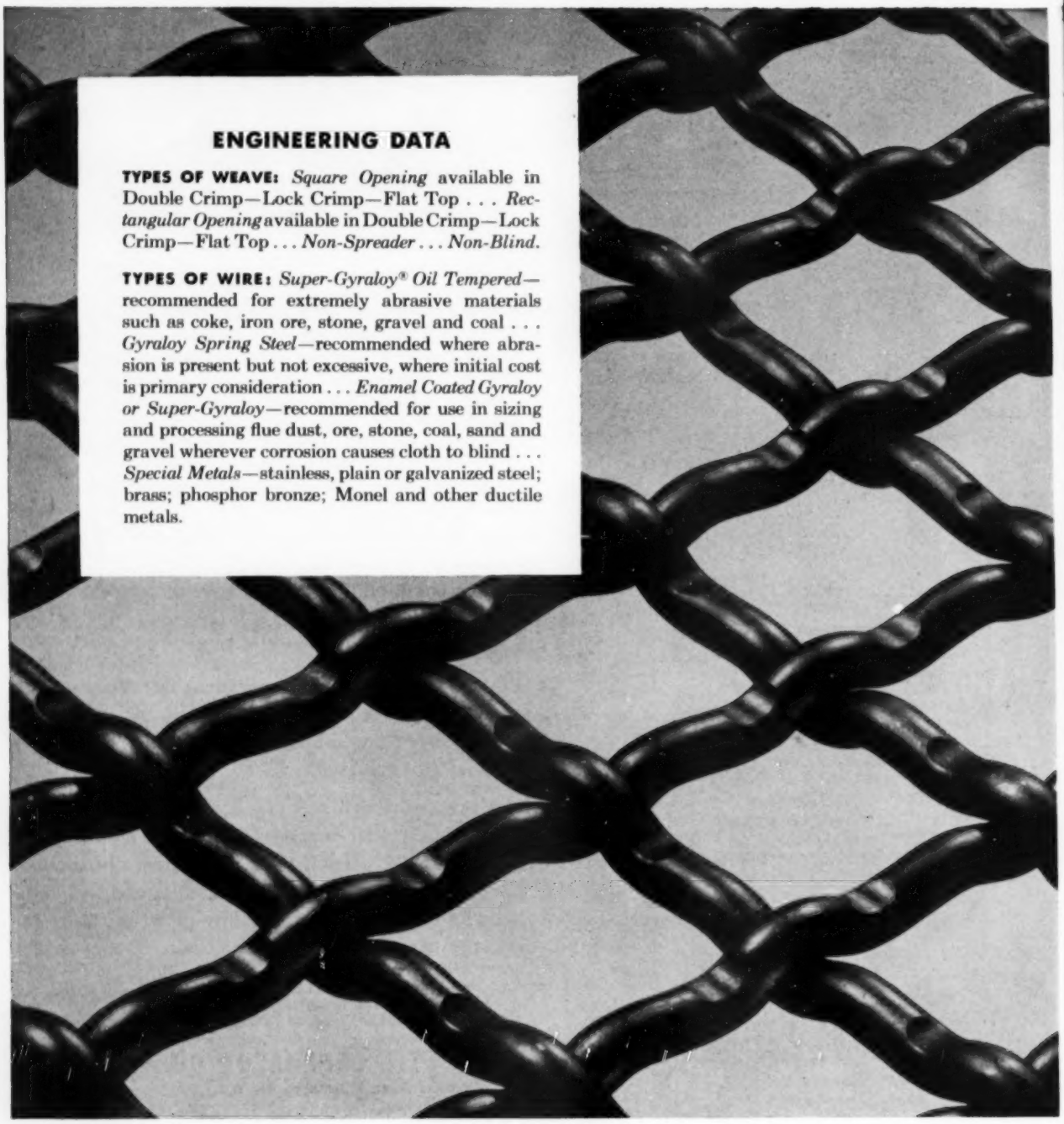
DINGS MAGNETIC PULLEYS—ELECTRIC AND NON-ELECTRIC PERMANENT

DINGS NON-ELECTRIC PERMA-DRUMS

DINGS MAGNETS

We'll Give You Better



ENGINEERING DATA

TYPES OF WEAVE: *Square Opening* available in Double Crimp—Lock Crimp—Flat Top . . . *Rectangular Opening* available in Double Crimp—Lock Crimp—Flat Top . . . *Non-Spreader* . . . *Non-Blind.*

TYPES OF WIRE: *Super-Gyraloy® Oil Tempered*—recommended for extremely abrasive materials such as coke, iron ore, stone, gravel and coal . . . *Gyraloy Spring Steel*—recommended where abrasion is present but not excessive, where initial cost is primary consideration . . . *Enamel Coated Gyraloy or Super-Gyraloy*—recommended for use in sizing and processing flue dust, ore, stone, coal, sand and gravel wherever corrosion causes cloth to blind . . . *Special Metals*—stainless, plain or galvanized steel; brass; phosphor bronze; Monel and other ductile metals.

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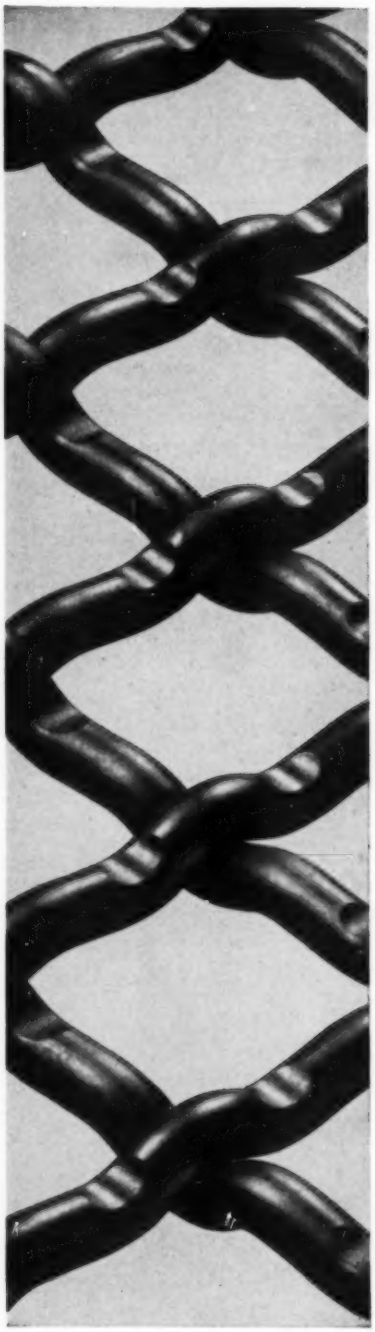
HEWITT-ROBINS

DIVISIONS: HEWITT RUBBER • ROBINS CONVEYORS • ROBINS ENGINEERS • RESTFOAM®

Screen Cloth Delivery



Increased Production Capacity Assures Faster Delivery For All Types Of Hewitt-Robins Screen Cloth

Now, we can give you faster delivery—*direct from our own modern plant*—of the finest quality screen cloth to meet your every need . . . Screen Cloth that gives you longer life, greater satisfaction on any type of screen, regardless of make . . . Screen Cloth that will provide you with highest efficiency, lowest cost per ton.

For shorter delivery on any type of Hewitt-Robins screen cloth send us this information:

1. Type of screen—Name of manufacturer—Model of machine.

2. Kind of screen cloth desired: Specify type *weave*—type of *wire*.

3. Size of clear opening or mesh and wire diameter.

4. Type of edge formation: Flat edges — Welded — Reinforced hook strips.

5. Length and width of panels (width measured from outside to outside of bent hooks)—Height and length of hook strips—Degree of angle inside of hook.

6. For rectangular, non-spreader or non-blind openings: Specify direction of long slot (which dimension of cloth it parallels).

7. For dewatering decks: Size of openings in mm—Single, double or no depressions—Round or triangular profile stainless steel rods.

WRITE FOR SCREEN CLOTH BULLETIN No. 113-A1

CHECK FOR INFORMATION ABOUT THESE JOB-TESTED PRODUCTS FOR YOUR OPERATION

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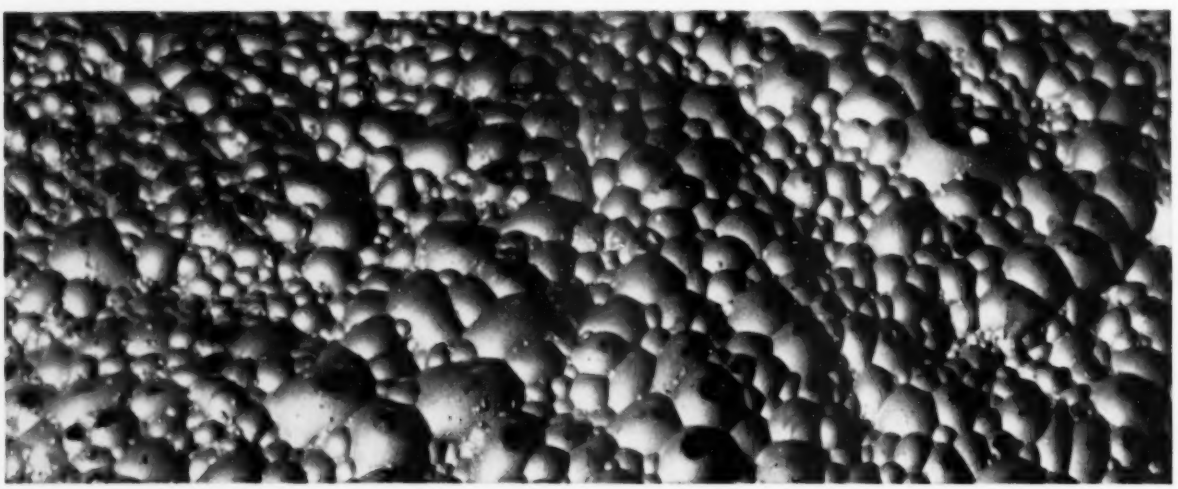
DOW

REDUCE FROTHER CONSUMPTION WITH DOWFROTH* 250

Quality frothing agent by DOW works harder on the machine for low-cost flotation with improved metallurgy



The ability of Dowfroth to build higher quality froth more economically is now well established. Many mills can testify to this. For example, at one mill Dowfroth 250 produced improved metallurgy with consumption one-fourth that of the previous frother used! For added economy, Dowfroth's water solubility results in its measurable return to the flotation circuit in water recovery systems.

Dowfroth 250 is essentially free of collector properties, making it particularly effective for selective flotation. This superior frother is also easy to handle, can be stored in any climate, and is readily available.

Consider the economy and efficiency of Dowfroth 250 for your operation. Send for a *free sample*, from Dow, Dept. OC 3-34. THE DOW CHEMICAL COMPANY, Midland, Michigan. *Trademark

you can depend on DOW CHEMICALS

DOW

"It Throws It Over Its Shoulder"

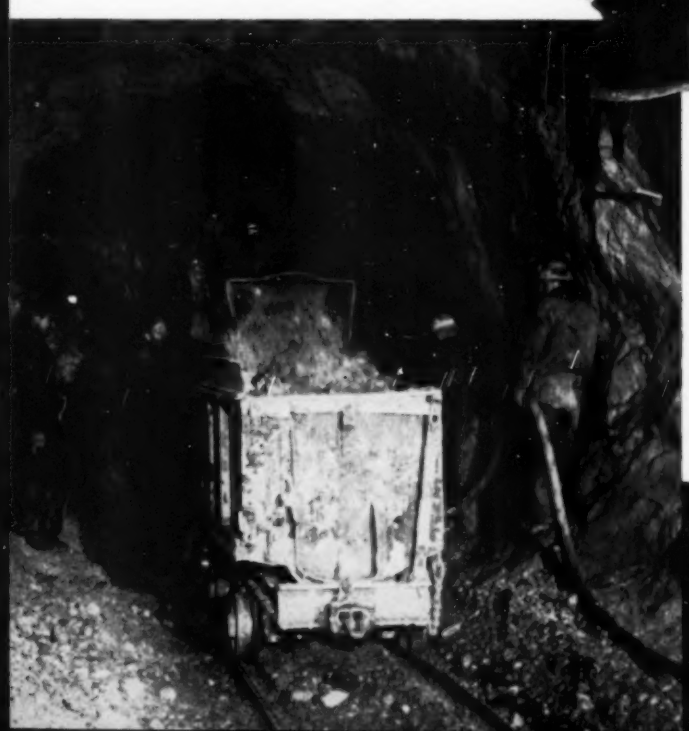
This is the way a famous news broadcaster explained the operation of an Eimco loader on a recent TV program remarking on the speed of the machine as seen in the Uranium fields.

Speed and dependability are the most desirable features in any loading machine today. These are the two most prominent features of all Eimco loaders.

The Eimco design permits faster, more efficient operation with greater safety than with any other loading equipment.

Its heavy-duty cast-steel construction makes it the most dependable, easiest to operate.

Write for information on Eimco loaders. There's an Eimco for every loading job.



Above — Eimco Model 21 Loader available for track gauges from 18" to 48" and with coupler to couple your car. Powered by two powerful Eimco 5-cylinder radial type air motors.

EIMCO A622

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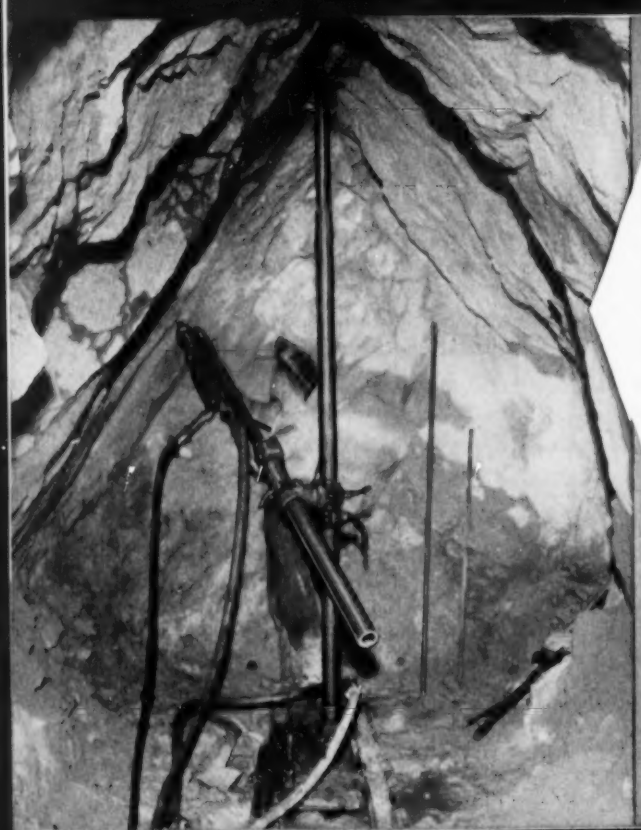


Miners like Le Roi-CLEVELAND HC23RW Reverse Air Feed Drifters

Management does, too

Faster Steel Changes! No swing or dump nuts to loosen and reset. Your miners simply swing drifter on feed cylinder and change steels. It's not only easy — it lets them drill out the round faster.

No Stuck Steels! Positive air feed keeps drills working at peak efficiency, avoids stuck steels.

Higher Drilling Speeds! Positive air feed plus proper force of blow and strong rotation give faster drilling speeds with both steel and tungsten carbide bits. You get longer bit life, too, and drill more footage.

Low Upkeep Cost! No feed screws or feed-screw nuts to wear. No complicated power-feed mechanism to give trouble.

Easy to Operate! Built to lighten the load on your miners. Feed controls conveniently located. Reverse air feed withdraws steel from hole quickly.

Faster Set-ups! The combination of Le Roi-CLEVELAND Air Feed Drifters and air columns gives you a unit that can be set up easily and quickly. And you can get the air column in any height you want.

drilling cycles

Le Roi-CLEVELAND *self-leveling* Mine Jumbo with four-foot steel-change Air Feed Drifter

Saves time drilling lifters! Lets your miners drill the right round for any ground!

You couldn't ask for more from a mine jumbo than the performance you get from this new Le Roi-CLEVELAND. It's got plenty of stuff. And the payoff for you is faster cycles, greater tonnage per man-shift, lower costs! Here's why:

Self-leveling, air-motor-powered arm, lets miners spot and space holes quickly and easily, for the most efficient fragmentation. They don't have to loosen a bolt or tilt a boom, to complete the drilling cycle.

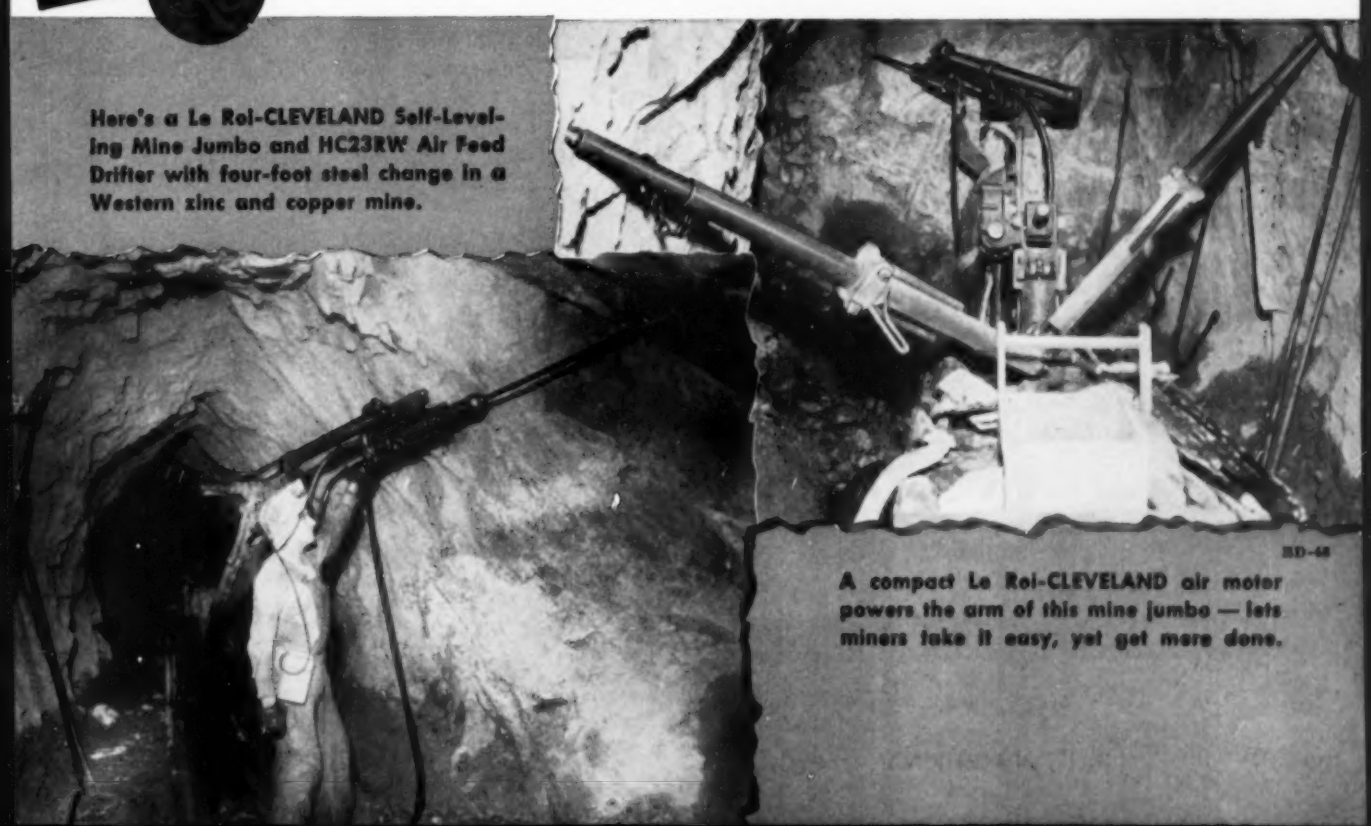
Exclusive rigid screw and gearing mechanism keeps the heading straight, cuts down overbreak and underbreak. Keeps the drifters in line, prevents the steel from binding, reduces chuck wear.

Offset arm provides plenty of clearance to drill lifters — without having to take time out to swing the drill under the arm.

You can get this Le Roi-CLEVELAND Self-Leveling Mine Jumbo in either single-arm or double-arm construction. Write for further information and see for yourself how either model can help you get more done every shift.

LE ROI COMPANY

CLEVELAND ROCK DRILL DIVISION
12500 Berea Road, Cleveland 11, Ohio
Plants: Milwaukee, Cleveland and Greenwich, O.



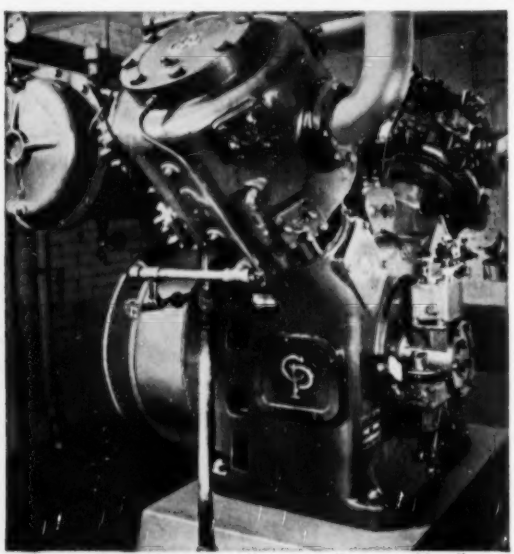
Here's a Le Roi-CLEVELAND Self-Leveling Mine Jumbo and HC23RW Air Feed Drifter with four-foot steel change in a Western zinc and copper mine.

BD-48

A compact Le Roi-CLEVELAND air motor powers the arm of this mine jumbo — lets miners take it easy, yet get more done.

Wherever air is needed

CP-315 Portable Compressor supplying air for drilling on bulk sampling operation.



With a Class Y Compressor there is no "space problem."

Built for dependable operation in any location, time-tested CP PORTABLE AIR COMPRESSORS have Gradual Speed REGULATOR that adapts engine speed to air demands, minimizing wear and assuring maximum operating economy.

CP Portable Compressors are available in gasoline and Diesel-driven models ranging from 60 cfm to 600 cfm.

* * *

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MEET THE AUTHORS

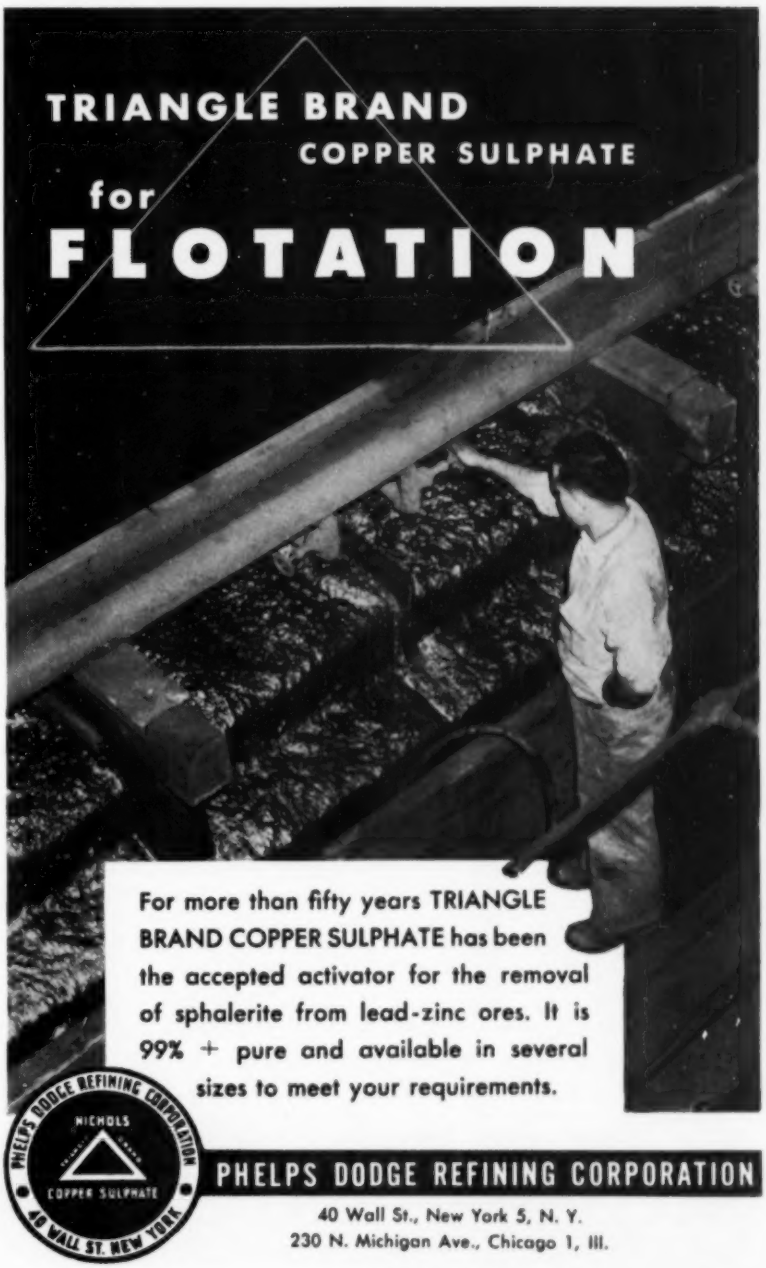
William T. McDaniel (Co-author, *A Method for Concentration of North Carolina Spodumene Ores*, P. 181) last appeared in MINING ENGINEERING as co-author of "New Method for Recovery of Flake Mica," published in March, 1951. He is employed by the North Carolina State College Minerals Research Laboratory as a mineral dressing engineer. Previous experience was gained with the TVA Construction and Commerce departments from March, 1942 to December, 1944. Mr. McDaniel holds a B.S. in Geology from the University of North Carolina. Combining professional work with pleasure, he enjoys prospecting at every opportunity.

Mason K. Banks (Co-author, *A Method for Concentration of North Carolina Spodumene Ores*, P. 181) is currently at the North Carolina State College of Agriculture and Engineering. After two years as a junior geologist and mining engineer with the Regional Minerals Section of the TVA, Mr. Banks spent three years with the Army Air Force, piloting B-24's during World War II. He holds a B.S. in geological Engineering from North Carolina State.

Philip N. Sales (Co-author, *A Method for Concentration of North Carolina Spodumene Ores*, P. 181) plays tennis almost as avidly as when a member of the varsity at North Carolina State College. He's been runner up to the winner of the Asheville, N. C. city championship twice and is president of the Asheville Tennis Association. Mr. Sales earned a B.S. in Chemical Engineering at N. C. State. He worked for Hercules Powder Co. for five years. He is now with the North Carolina State College of Agriculture and Engineering.

Rolland Blake (*Research on the Cutting Action of the Diamond Bit*, P. 187) is a graduate of the University of Minnesota, holding a Bachelor of Geological Engineering, and an M.S. in Geology. While at school he belonged to the Mines Society of the U of M, the Geology Club and the Ski Club. He still takes to the Minnesota hills with his skis when time allows. Archery and an assistant scoutmastership of Troop No. 1, Hibbing, Minn., account for much of his remaining free time. In 1952 Mr. Blake went to the Cleveland Cliffs Iron Co., as a geologist.

Gerald C. Mathis (*United States Gypsum Co. Mine*, P. 177) is a mine superintendent with U. S. Gypsum Co., living in Lewistown, Mont. A graduate of South Dakota School of Mines & Technology, he has a B.S. in Geological Engineering. While at school he held several class offices and was in Who's Who Among University and College Students in 1949-50. He styles himself an unsuccessful hunter and fisherman. Part of his time is taken up with duties as vestryman of Episcopal Church and as leader of a church youth group.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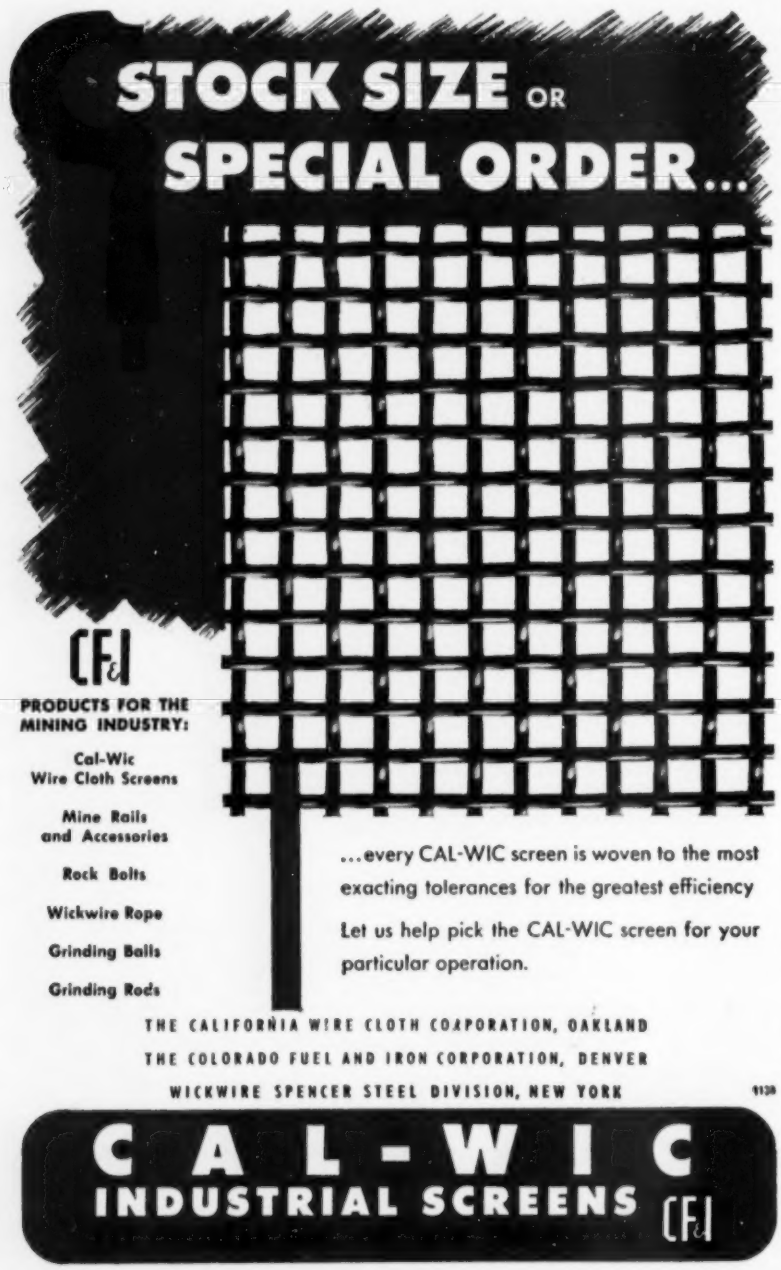
Colliery Working and Management, by H. F. Bulman, and Sir R. A. S. Redmayne. *Anglobooks,* $10.50. 393 pp., 1952.—Recent and momentous change in the British coal mining industry has necessitated changes and additions in the beginning of the volume. A new chapter has been added covering new developments. The remainder of the book has remained intact.

Field Geology, by Frederic H. Lahee. *McGraw-Hill Book Co.,* $8.50., 883 pp., 1952.—This field manual has been in print for more than 25 years. Now, the author presents a thorough revision bringing up to date existing material and includes all new developments in such areas as geophysics, well-logging and air photography. Phraseology has been revised to clarify definitions, a short section on underground surveying has been added, new articles on electronic methods of location and airborne magnetometer surveying adds much to the book.

Hydrometallurgy of Base Metals, by George D. Van Arsdale, prepared with the assistance of the Dorr Co. staff. *McGraw-Hill Book Co.* $9.50, 370 pp., 1953.—The recovery of base metals by leaching is fully and practically covered. With special reference to copper, the book gives much helpful technical and economic information on the hydrometallurgy of lead, zinc, antimony, cadmium, vanadium, uranium, and radium. Included is information on uranium leaching as recently developed in the Colorado Plateau area, the treatment of cobalt in Rhodesia, production of electrolytic manganese and antimony, and the heap leaching of copper ores. Processes and plants, equipment, materials, and economic considerations are detailed. The last two chapters cover the history and future of hydrometallurgy.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Recent U. S. Patents

2,624,461 Float removal device for rotable type Heavy-Media separators. (1/6/53) *American Cyanamid* Co.

2,624,702 Separation of nickel from cobalt containing solutions. (1/6/53) *Societe Generale Metallurgique de Hoboken, Netherlands.*

2,625,384 Mining operation (for recovering sodium carbonate from Trona beds.) (1/13/53) *Food Machinery & Chemicals Corp.*

2,625,462 Process for producing manganese carbonate, (1/13/53) *Reginald S. Dean*

2,625,464 Roasting of sulphides (to yield sulphur dioxide.) (1/13/53) *The Dorr Co.*

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RI 4921 Maple Mountain - Hovey Mountain manganese project, Central District, Aroostook Cty., Me.—with metallurgical investigations. 118 pp.

RI 4924 Anthracite Mechanization-mining investigation, Progress Report 7, Longhole-retreat, mining of steeply dipping anthracite bed. 10 pp.

RI 4926 Selected bibliography of coal gasification. 28 pp.

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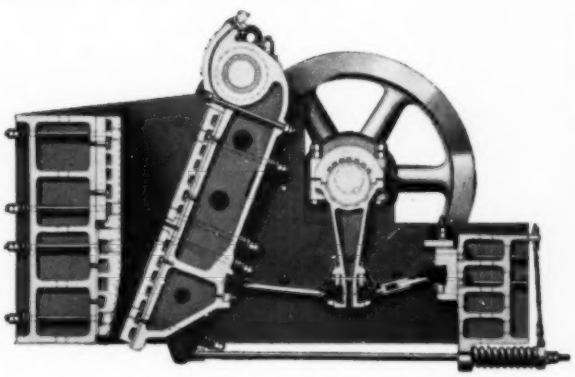

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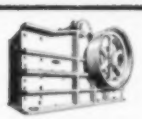
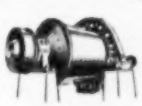

Jaw Crushers

Gyratory Crushers


Grinding Mills

Kilns, Coolers, Dryers

Manufacturers News

New Products • *FILL OUT THE COUPON FOR MORE INFORMATION* • Equipment

Jackdrill

Completely integrated air-leg rock drill combination is being offered by *Ingersoll-Rand Co.* as the JR-38 Jackdrill. Most radical innovation is

built-in air coupling between drill and feed leg. The feed leg is detachable to permit Jackdrill use as drifter, stoper or Jackhammer. **Circle No. 1**

Plastic Pipe

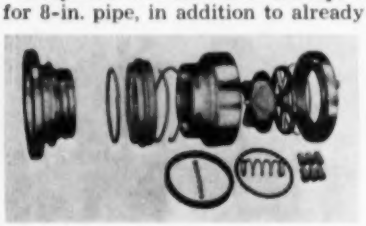
The Mechanical Goods Div. of *U. S. Rubber Co.* has published a general letter covering dimensions, installation, and properties of Uscolite pipe and fittings. **Circle No. 2**

Feeder

Com-Bin revolving feeder made by the *Pulva Corp.* is claimed to store and feed uniformly any non-free flowing material such as wet filter cake, sludge, or mastic, as well as dry materials. **Circle No. 3**

Coupler

Snap-Tite Inc. announce a coupler for 8-in. pipe, in addition to already



available units from ¼-in. size. Couplers connect or disconnect without tools, swivel 360°, and automatically shut off flow when male part is removed. **Circle No. 4**

Exploration Tool

Radore geophysical technique employs radio waves to detect electrical contrast existing between many mineral deposits and the surrounding country rock. *William M. Barret, Inc.*, will rent, or sell outright, complete sets of Radore apparatus and conducts domestic and foreign contract surveys with its own crews if desired. **Circle No. 5**

Heated Screen

A new method of heating screen cloth electrically to prevent blinding from wet materials has been announced by *Hewitt-Robins Inc.* Current is carried by short insulated cables attached to copper bars under the screen cloth and in direct contact with it. Reduced power losses, easier cloth changing, and protection of current distribution bars are advantages claimed. **Circle No. 6**

Films

Contractors, mine and quarry operators, and industrial concerns may make arrangements to borrow 16mm sound-color films from the *Euclid Road Machinery Co.* Films show power earth moving equipment, such as the Twin-Power scraper, in action. **Circle No. 7**

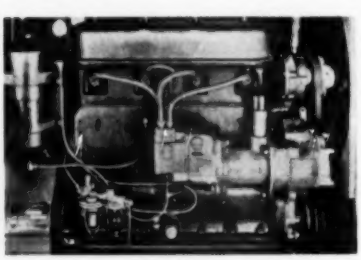
Pulmonary Ventilator

Designed to alleviate symptoms of the silicotic, the Pulmonary Ventilator is announced by *Mine Safety Appliances Co.* It provides mine

hospitals and dispensaries with a simpler technique for caring for a larger number of patients requiring treatment by intermittent positive pressure, and requiring the distribution of drugs to the bronchial tubes under pressure. **Circle No. 8**

Ignition Shielding

Titeflex Inc. has perfected ignition shielding for *Le Roi* mining and construction machinery. A flexible



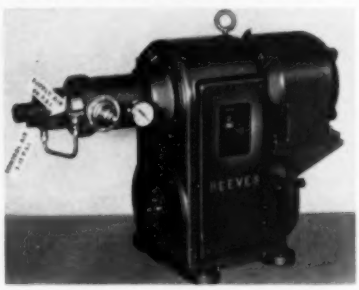
metal hose is designed to provide durable protection against moisture, abrasion, vibration, and mechanical damage. **Circle No. 9**

Coal Drills

Carboloy Dept. of *General Electric Co.* has announced a broadened line of coal mining tools. Additions are 2½ and 2¾-in. auger drills and a 1⅜-in. pin timbering drill, all tipped with tungsten carbide. **Circle No. 10**

Motor Drive

Conoflow control, now available on all integral horsepower *Reeves Pulley Co.* Vari-Speed Motodrives



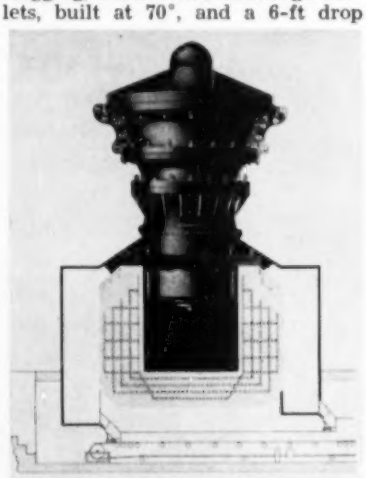
up to 25 hp, is designed to be operated by any pneumatic control instrument with instrumentation air pressures of 3 to 15 psi. **Circle No. 11**

Winch-Hoists

Vest-pocket hoists weighing but 8¾ lb, and capable of lifting 1½ tons are available, together with inexpensive accessories, from the *Lug-All Co.* Descriptive literature contains hoisting hints. **Circle No. 12**

Crusher

The new *Kennedy-Van Saun* gyratory crusher, designed to eliminate clogging, utilizes two discharge outlets, built at 70°, and a 6-ft drop



separates rock and ore from clay. Capable of reductions to as fine as 1/16 in., power is supplied through gearless construction with synchronous motor built into the pulley assembly. **Circle No. 13**

FLOATING WITH EASE . . . . new all Nylon, 65-in. Earth-Mover tire whose shallow tread enables it to float on top of sand and loamy soil. B. F. Goodrich worked with R. G. Le Torneau Co. in developing the tire, which has been under test for two years. Use of Nylon in cord body enables it to withstand flexing at relatively low 20 to 25 lb air pressures.

Free Literature

(14) CLASSIFIERS: Illustration and description of design features, dimensions and capacities of Wemco S-H (Special-Helix) classifiers is provided in a bulletin from the *Western Machinery Co.*

(15) MOTORS: A bulletin from *U. S. Electrical Motors Inc.* provides complete information about their new totally-enclosed type SS mo-

tors. Built for both hazardous and non-hazardous service, the construction features asbestos protected windings for greater motor life.

(16) JAW CRUSHERS: Bulletin from *Smith Engineering Works* describes the nine sizes of Telesmith jaw crushers, ranging in size from 10x16 to 30x42 in.

(17) PLASTIC PIPE: Brochure from Plastic Products Division of *Triangle Conduit & Cable Co.* gives chemical and physical characteristics of Triangle's four types of pipe. Included are simple directions on installing and joining the pipe.

(18) PHOSPHORIC ACID: *The Dorr Co.* has available a technical reprint, "The Manufacture of Phosphoric Acid by the Wet Process," by W. C. Weber. The chapter on wet-process phosphoric acid from the book, "Phosphoric Acid, Phosphates and Phosphatic Fertilizers," now in reprint form, consists of 36 pages on all phases of manufacture by the sulphuric acid or wet process. Twelve pages are devoted to equipment, and sections are included on byproducts, costs, installations, and references.

(19) FLEXIBLE TUBING: Spiratube and Flexflyte spiral wound tubing for ventilation, fume and dust removal, and materials handling are described in an 8-page bulletin from *Flexible Tubing Corp.* Also included are detailed specifications, air friction charts, and application data.

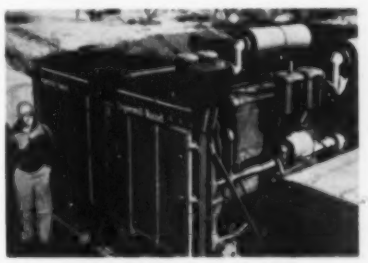
(20) TWO-WAY RADIO: Titled "Instant Communication" *General Electric Co.'s* booklet on two-way radio is slanted to those businesses using materials handling and emergency service equipment, and shows G-E equipment now available for a wide variety of applications.

(21) DRILL BITS: Calumet Division of *Calumet & Hecla Inc.* announced release of a booklet on Liddicoat drill bits. Featured are type L bits for easy-to-drill ground and type H for strong rock, abrasive ground. The booklet points out that Liddicoat one-use bits chip rather than pulverize, to provide faster drilling at decreased cost.

(22) RUST PREVENTION: A 16-page general catalog on stopping rust by proper surface preparation and application of various primers and coatings has been issued by *Rust-Oleum Corp.*

(23) BELT CONVEYORS: The new *Jeffrey Mfg. Co.* catalog is said to be virtually a handbook on the subject of belt conveyors; the "information within its covers is the outgrowth of nearly 50 years of experience in furnishing conveyors to practically every industry."

(24) DIESELS: *Ingersoll-Rand Co.* has a bulletin on their TS series



"smaller, lighter, but fully heavy-duty" Diesel engine. It is a 7x8½ in., 900 to 1000 rpm Diesel in the 200 to 400 hp class.

(25) WIRE ROPE: Pocket size handbook offered by *A. Leshen & Sons Rope Co.* aims, "to help users become more expert wire rope buyers," with data on rope construction, lubrication, loads, safety factors and attachments.

(26) MINERAL EXPLORATION: *Engineers Syndicate, Ltd.* has a brochure listing scintillation and Geiger counters, ultra violet lamps, and Carpco high tension and magnetic separators. Two articles with the listing discuss discovery and evaluation of Uranium, rare earth, and other mineral deposits.

(27) WROUGHT IRON: Five tests for positive identification of wrought iron pipe are described in a brochure published by *A. M. Byers Co.*

Mining Engineering **February**
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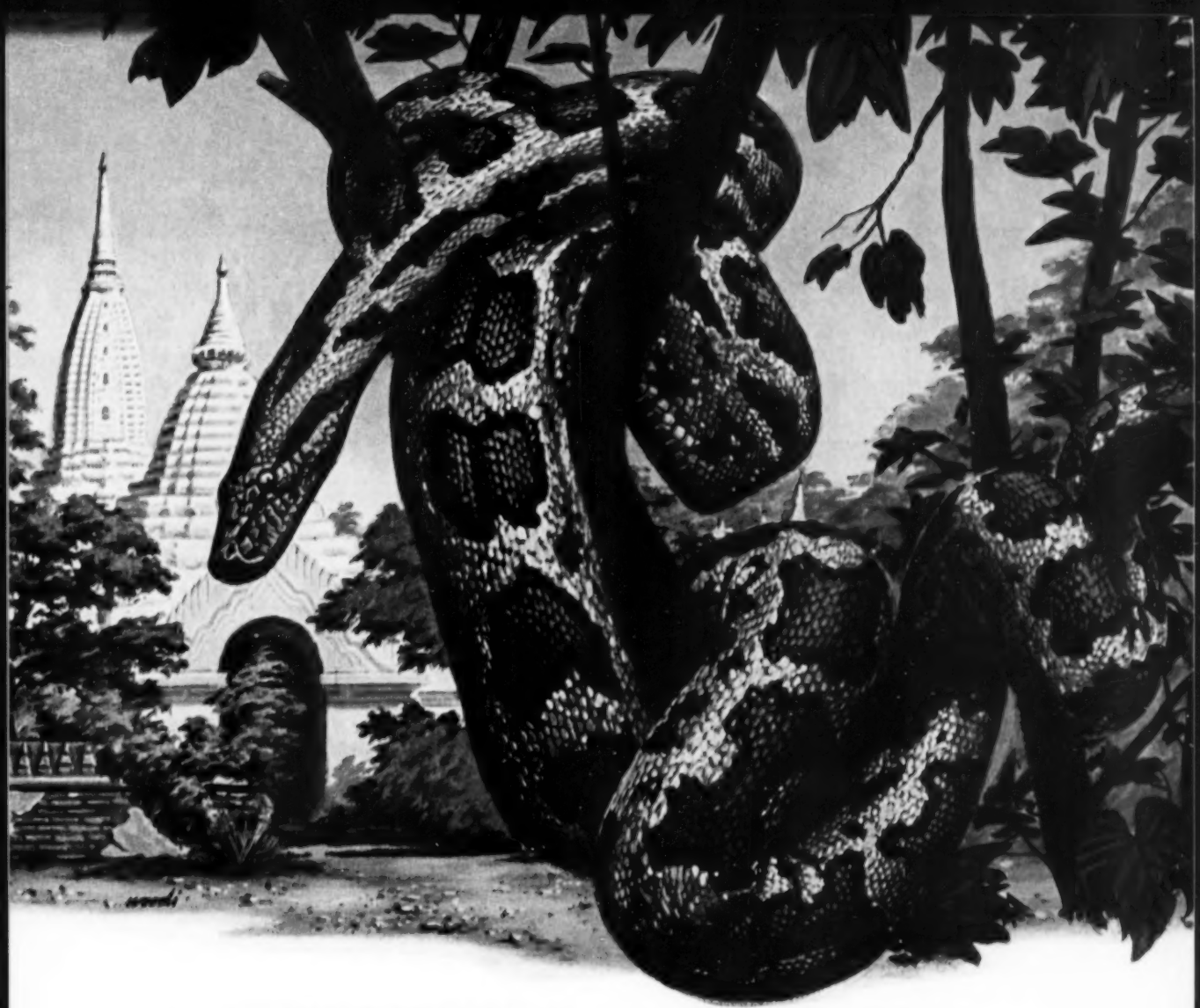

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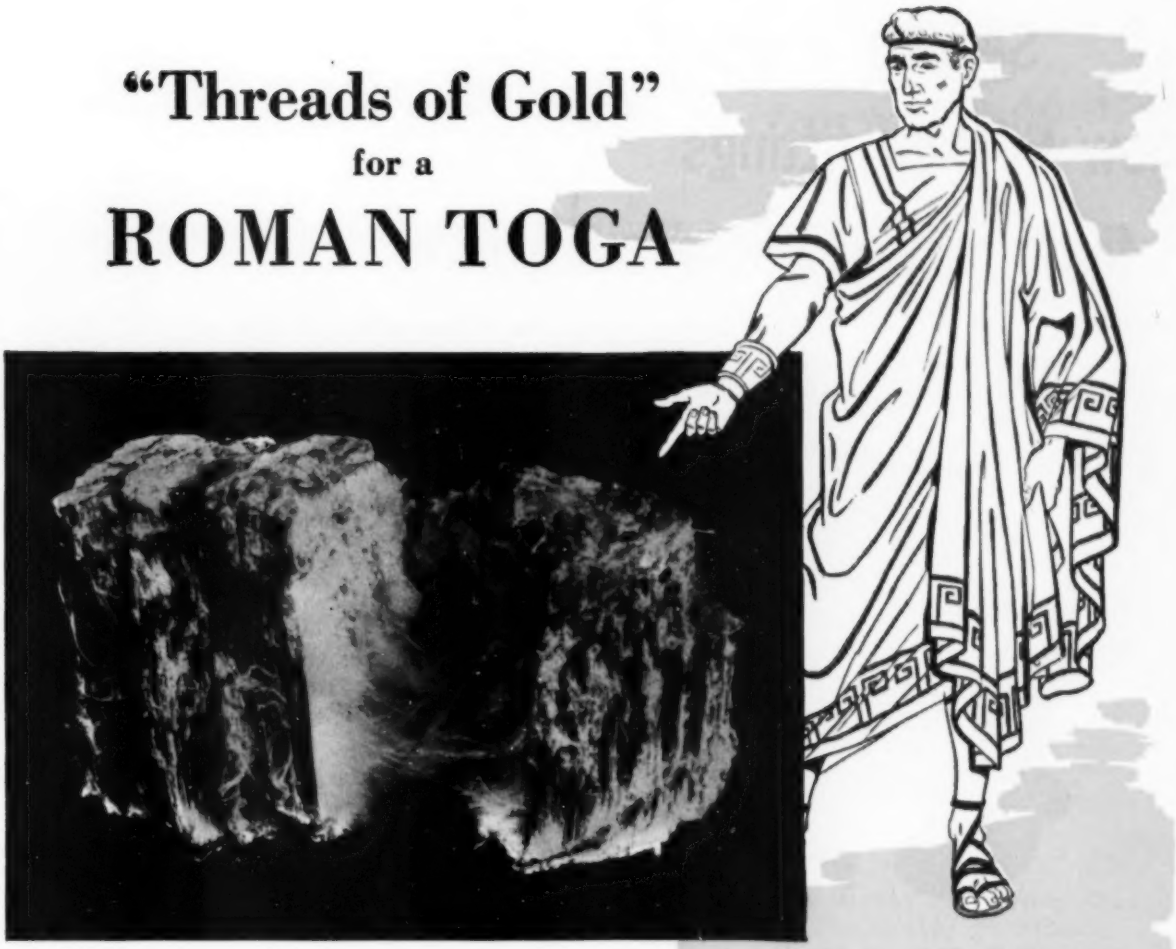
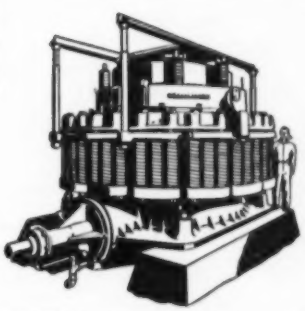


The mineral *Chrysotile,* meaning golden fibers, or threads, supplies over 90% of the world's asbestos requirements. Called the "miracle mineral" by the ancients, the Roman naturalist Pliny (23—79 A.D.) refers to the use of such material as "a rare and costly cloth" used for the funeral garments of kings.

The secret of the great usefulness of asbestos lies in its unique combination of fibrous structure, fire and water resistance, flexibility and strength. Since the profitable recovery of asbestos fiber depends upon fine crushing without destroying fiber length, a crusher that will perform such functions economically, and will produce large quantities of finely crushed material, is essential.

Proof of the world-wide acceptance of *SYMONS* Cone Crushers in asbestos production is found in the field, where practically every major producer employs these high capacity, economical machines . . . *as in all of the great ore and industrial mineral operations the world over.*

NORDBERG MFG. CO., Milwaukee, Wisconsin



SYMONS Cone Crushers . . . *the machines that revolutionized crushing practice* . . . are built in Standard, Short Head, and Intermediate types, with crushing heads from 22 inches to 7 feet in diameter—in capacities from 6 to 900 tons per hour. C252

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Heretofore, Hudson Coal used extra thick gray iron fittings for this service.

But the Ni-Hard fittings . . . installed in 1950 to handle the highly abrasive sand, waste and water mixture at 3,000 GPM . . . now appear capable of lasting three to four times longer than the thicker sectioned gray iron fittings.

Use Ni-Hard on *your* tough jobs . . . for lowest ultimate cost.

Investigate Ni-Hard. Get full information . . . mail the coupon now.

At the present time, the bulk of the nickel produced is being diverted to defense, but nickel is obtainable for the production of Ni-Hard for many end uses in defense and defense supporting industries. There are authorized producers, from coast to coast, equipped to produce Ni-Hard castings in all common forms and shapes.

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Please send me free booklets entitled: "Engineering Properties and Applications of Ni-Hard" and "Buyers' Guide for Ni-Hard Castings."

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THE INTERNATIONAL NICKEL COMPANY, INC.

67 WALL STREET
NEW YORK 5, N.Y.

Mining headlines in 1952 dealt mainly with expansion as the industry aimed for an ever increasing production to meet the nation's needs. Huge sums were expended for equipment, research, and development. Headlines told part of the story.

Negotiations between San Manuel Copper Co. and the RFC finally resolved in a $94 million loan for the development of low grade Arizona ores. Magma Copper, parent firm was to supply an additional $8 million. Kennecott Copper Co., deepening its Deep Ruth Shaft of its Ruth, Nev. mine, announced that the shaft would be in full production in 1953.

Steady progress was being made at Copper Range Co.'s White Pine Copper Co., in Michigan, as milling and mining facilities began to take shape. Shipments of low grade copper ore began flowing from Anaconda Copper Co.'s greater Butte project to enlarged smelting facilities at Anaconda, Mont. Ore reserves at the greater Butte project were being revised upwards as development progressed.

American Smelting & Refining Co. managed to beat nationalization of Bolivian tin mines by turning its Coro Coro development back to the country. In the meantime, the U. S. Government signed a limited pact with Bolivia for some 6000 to 7000 long tons of tin at Peruvian and Chilean ports after months of price negotiations.

Government-owned Nicaro nickel plant, Cuba, operated by Nickel Processing Co., came into full production by the end of 1952, according to DMPA. Falconbridge, International Nickel Co., and others were stepping up production to meet world demands. The area southeast of Sudbury was the scene of a staking rush as companies used helicopters and two-way radio to get men into a section where anomalies supposedly represented norite and other basic rock favorable to nickel.

First uranium rush near Uranium City in Canada's north country took place in 1952. It was a far cry from the old gold rushes with prospectors using the latest scientific devices to stake claims. In 1952 added uranium from U. S. phosphate sources, Australia and South Africa strengthened U. S. position. South Africa's gold mines, with American and British financing, began to extract uranium through an undisclosed process.

Reserve Mining Co. received a $149 million loan from the RFC for commercial taconite production. It will take two years for the four-story Allis-Chalmers crusher to be installed at Babbitt, Minn.

Chemical Construction Co. disclosed a new chemical process for the smelting of base metals. Howe Sound, at its Salt Lake City refinery, began to use the process while National Lead Co.'s plant at Frederickstown, Mo., is scheduled to begin sometime in 1953. Sherritt Gordon expects to combine the Chemico reduction with an ammonia leach method.

Plans to step-up South Korean tungsten production would double output and supply about one-third of world needs. The U. S. signed a pact which covers all South Korean tungsten production.

Strips, Clears, Pulls scoop

says veteran Illinois dirtmover about Tournadozer

After 18 years of coal mine stripping and other dirtmoving, Ivan Wright, Peoria, bought his first rubber-tired Tournadozer last year. Now, with more than 2500 hours on this 19 m.p.h. rig, he says, "There's not a crawler-type machine made that will move the amount of dirt Tournadozer will!" For example:

Stripping--On job pictured here, Tournadozer, working alone, stripped 40 ft. of overburden at a small coal mine near Glasford, Illinois. Tournadozer removed all slate and refuse including 1 foot of tough cap rock so that coal had only to be shot and hauled out.

Clearing—Wright assigned 2 dozers to clearing brush and trimming banks for a road. He put a Tournadozer in one ditch and a crawler in another. "Tournadozer walked away from the crawler," he says. "Never found a tree the Tournadozer couldn't take out . . . takes a tree up to a foot in diameter in one pass."

Pulling a scoop—On typical earthmoving, Wright's Tournadozer pulling a 15-yd. scraper averaged 15 trips (150 *pay* yds.) of heavy clay hourly on 400′ cycles, according to time studies made by a Government Engineer. "Working with a scoop," says Wright, "you can load in 2nd gear and dump in 3rd . . . can double production of a crawler-pulled scraper. Tournadozer is the best rig to pull a scoop that I've ever seen or used." Rig has 186 h.p. with 4-wheel drive.

Dozing up steep grades—"Working in 6 to 7′-deep channel," reports Wright, "Tournadozer would come up 3-to-1 slopes with a load whereas crawler *could not* make the slopes with a load." (Tournadozer's constant-mesh transmission lets you change speed under load without loss of vital momentum . . . 186 h.p. and 4-wheel drive give you plenty of power to work up steep, slippery grades.)

TWICE AS FAST ON 85% OF YOUR DOZING WORK

LETOURNEAU LET EQUIPMENT

Removing overburden at mine near Glasford, Tournadozer, working alone, strips 40 ft. of clay, sand, shale and soapstone, moving overburden on average of 200 ft. One foot of cap rock just above coal seam was also removed by Tournadozer, leaving coal ready to shoot and haul out.

faster . . .

Job-to-job moves — In 2500 hours of scattered assignments, Tournadozer has never been on a trailer . . . travels any time, anywhere over main roads, under its own power, at speeds to 19 m.p.h. "Up to 50 miles, you can move Tournadozer as fast as you can a crawler with a truck," says Wright. You waste no time loading, blocking . . . save time shuttling between assignments or traveling to neighboring spreads.

Ease of operation — Comparing Tournadozer with crawler rigs, Wright reports, "Tournadozer is much easier to operate—no work to it." No wasted time or effort clutching . . . Tournadozer changes speed *instantly* with movement of speed selector switch. Big 18.00 x 25 low-pressure tires take up many of the shocks of uneven ground . . . save wear and tear on operator as well as machine.

Be your own judge of what Tournadozer can earn on your operations. To help you make estimates, ask your LeTourneau Distributor for owner-verified field reports covering all types of working conditions . . . or have him demonstrate one of these high-speed rigs in your pit. Meanwhile, write direct for bulletin TD-117 describing design and construction.

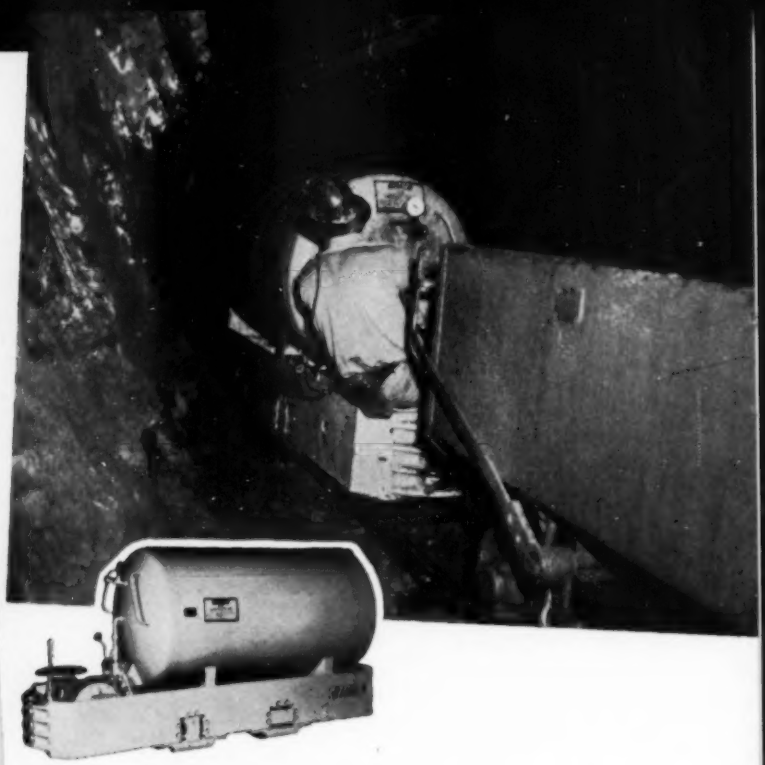
Tournadozer—Trademark Reg.U.S.Pat.Off. D-145-CM

After 2500 hours, Tournadozer tires still have about 85% of original tread. During this period, the rig has been 95% mechanically efficient.

LETOURNEAU PEORIA ILLINOIS **TOURNADOZERS**

EIMCO 2-Speed AIR LOCOMOTIVE

for { SMALL MINES
CONSTRUCTION JOBS
GATHERING
EXPLORATION DRIFTS
SWITCHING
and many other uses



The Eimco Air Locomotive is the answer to economical car handling underground. Eimco has developed the first two-speed, constant-mesh transmission to be used on any air locomotive. Starting in low gear to get the load in motion you shift immediately into high gear.

ADVANTAGE
This means you get more haulage distance per cubic foot of air consumed.

There are many other advantages in the Eimco Air Locomotive. Here are a few:

1. Longer hauls with greater load. 2. Two speeds forward and reverse. 3. Neutral for free wheeling. 4. Articulating axle assembly. 5. Efficient Eimco made air motor. 6. Registered ASME code receiver. 7. Parking brake. 8. Safety centering throttle.

EIMCO A421

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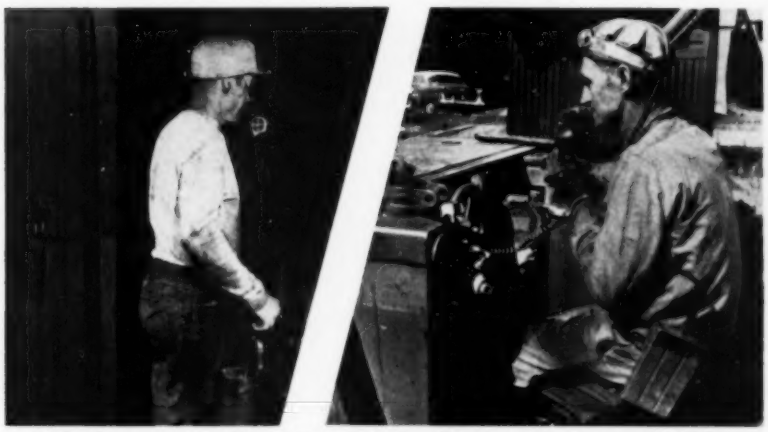


Man, left, at dumper of Mathies mine near Finleyville, Pa. is in constant communication with all motormen, effectively controlling traffic and assuring smooth movement of cars over the double track line. Motorman's phone is conveniently located on junction box cradle, while the speaker is nearby.

Mathies Mine Expands Communications System

Mathies mine, near Finleyville, Pa., currently mining 11,000 tons of bituminous coal daily, has been expanding communications to meet the needs of a steadily increasing production schedule.

Each of three main line locomotives and five gathering motors operating over the double-tracked haulage system is equipped with the MSA MinePhone. The unit comprises a transmitter and receiver using trolley wire for instant voice communication. Units are also located in the car dump, lamphouse, and on two spare locomotives at the mine shop.

Installation began in 1949. With the present system, the car dump operator can be in immediate contact with all motormen, assuring efficient traffic control and uninterrupted flow of loaded cars out of the mine and empties on the way back to work faces.

The system includes circuits based on inductive train communication methods used by many railroads. It employs a frequency-modulated carrier of 88 kc, with an average modulation range of plus-or-minus 3 kc which does not interfere with the conventional mine telephones.

Aluminum Plentiful By Middle of Year

"There will be plenty of aluminum for all who want it before the middle of 1953, unless there is an extension of hostilities," Richard S. Reynolds, Jr., president of Reynolds Metals Co., predicted.

He estimated 1952 production to be close to 1.9 billion lb, or about 11 pct greater than the previous year's output. He noted however, that "it does not fully reflect the expansion already completed."

"The big surge in production is coming in 1953 and 1954, with an output of 2.5 billion lb expected in 1953 and 3.0 billion in 1954.

He said that Reynolds Metals set a new record for the company with an estimated "552 million lb, or 13 pct higher than 1951 production, and almost three and one half times its peak World War II output. When expansion plans are completed in 1953 annual capacity will be 830 million lb, more than five times as much as at the close of the war."

British Coal Mines Miss Year's Goals

British coal mines missed both their objectives in 1952. The nationalized mines failed to dig the coal needed or to balance their books.

The National Coal Board spent huge sums to modernize the collieries in an attempt to raise production. Output rose steadily since World War II with 1951 production slightly under 223 million tons. But the goal set last January for 1952 calling for 226 million tons was not reached. Output was less than 225 million tons.

Disgruntled miners, unhappy about pay scales, were blamed for the dwindling output. The pay issue represents another headache for the Coal Board, who also faced a deficit of $1.4 million for the first six months of 1952.

Low Zinc Prices Close Alcoa Mine

Alcoa Mining Co., announced that it will suspend operations at its Hutson mine, near Salem, Ky., because of low zinc prices, January 15.

The Aluminum Co. of America subsidiary announced that the low market has made zinc mining unprofitable. About 70 men were employed at the mine, with a production of about 5000 tons of zinc annually. Alcoa said the shutdown would not affect other company operations, with most of the men at Hutson absorbed in the mining firm's fluorspar operations in the same area.

Alcoa opened the Hutson mine in October, 1950, when zinc supply was low and prices high. Most of the mine output, after processing by other manufacturers, was used by Alcoa.

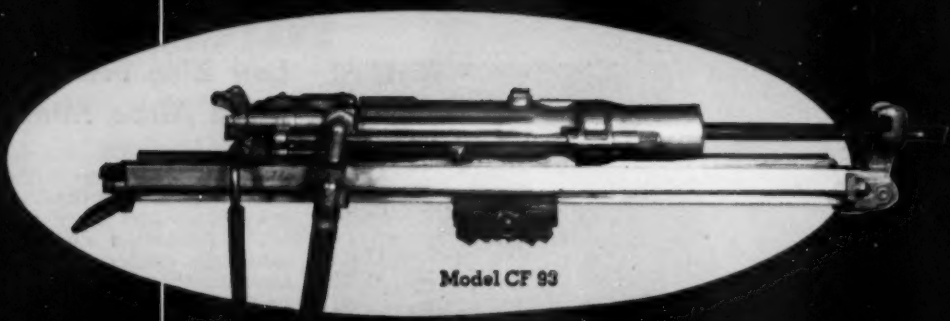
Uranium Pilot Plant Nears Operation Date

Construction is under way on a new uranium pilot plant designed to demonstrate new and cheaper methods of extraction, according to the Atomic Energy Commission and American Cyanamid Co.

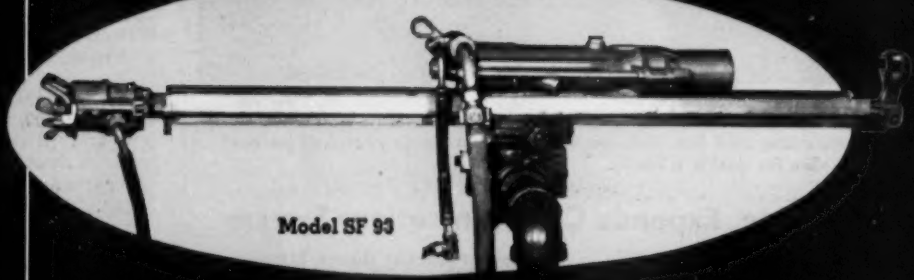
Operation is scheduled to begin by March 1, 1953. Frank H. MacPherson, acting manager of the AEC's operations office at Grand Junction, Colo., said the plants purpose will be to "demonstrate on a commercial basis the possibilities for substantially reducing the cost of milling uranium ore."

It has been announced that a staff of 25 engineers and technicians will operate the plant.

Colorado Plateau area has been the scene of stepped up uranium milling and mining operations.



Model CF 93



Model SF 93

Introducing the 3½" GARDNER-DENVER 93
...the EAGER DRIFTER!

Equals most 4" machines in *drilling speed*.
Exceeds all other 3½" drills in *hole-cleaning ability*.
Maintains correct bit pressure *automatically* — regardless of ground changes.
Long feed aluminum alloy mounting — with automatic feed motor on drill backhead or on guide shell.
Ask for Bulletin DD-2 — it gives complete specifications.

SINCE 1859 **GARDNER-DENVER**

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THE QUALITY LEADER IN COMPRESSORS, PUMPS AND ROCK DRILLS

Continuous Miner Adds 4760 Sq Ft To Warehouse

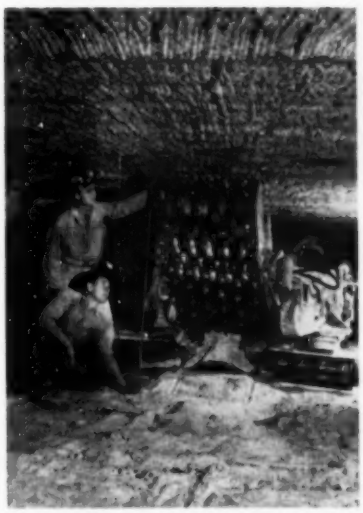
Mechanical Monster Eats Through Potash

A mechanical monster, with a tremendous appetite stole the underground show at Potash Co. of America recently. The *monster* is PCA's newest mining machine, the Joy Continuous Miner, which played an important role when the first steps were taken to enlarge the mine warehouse.

The machine, weighing 36,000 lb, was used to cut an L-shaped room which will add 4760 sq ft to warehouse facilities. The continuous miner is one of three of such machines made by Joy and used at PCA on an experimental basis. Two others have been employed in development work in the mine.

Originally designed for use in coal mines, the machines came into use after World War II. PCA was the first company to employ them in potash mining. The machine bites into ore with 144 teeth, which are bits fastened to six chains. The chains are mounted on the head of the machine and powered by two 65-hp motors.

A small hole was the first sign of a breakthrough to the warehouse. As storekeeper peers through opening, men on the other side line up the continuous miner to make last full-scale cut.



Two Potash Co. of America miners measure the height of the *back* after making a cut with continuous miner. Machine has been used by PCA on an experimental basis.

Originally Designed For Coal Mining Operations

Potash cut out of the face is carried over the head of the machine and back to a conveyor. There it is dumped into a waiting shuttle car, or another conveyor.

The head of the machine can be swung either horizontally or vertically. Two screw-type conveyors, mounted on either side in front of the machine, gather up potash which drops from the head.

Operated from the right side, the machine is mounted on treads.

Following the breakthrough, a pause was necessary to change the 144 bits set in the six chains on the head. Two 65-hp motors drive the head. Two men are usually required for the operation.

Continuous miner is moved slowly forward as it finished off one side of the breakthrough. The miner standing to one side is giving instruction from inside the warehouse. Potash cut out of the face is carried over the head of the machine to a conveyor.

A. YUBA No. 152, originally built with 10 cu. ft. buckets and 80-ft. digging depth for Emigrant Dredging Co., dredging gold in Montana, 1941.

B. YUBA crew dismantled No. 152 for new owners, Nechi Consolidated Dredging, Ltd.; moved it by truck and rail to New Orleans, there rebuilt it for ocean tow to Colombia.

C. YUBA No. 152, now renamed Santa Margarita, enroute to Colombia. Changes in structure and equipment to fit the new ground were made during move and rebuilding.

If you, like Nechi Consolidated Dredging, Ltd., need a dredge moved or rebuilt—YUBA can help you. We are dredge specialists with more than 40 years of experience in designing, building, moving, and rebuilding. YUBA-designed dredges are used to handle all sorts of alluvial material—for building dams, canals, levees, etc., and in digging such minerals as monazite, ilmenite, scheelite, cassiterite, platinum, gold, zirconium, garnets and sapphires.

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46.

Taconite Report Relates Allis-Chalmers Progress

An interim report on pilot plant work for heat hardening pellets from magnetic taconite concentrates at Allis-Chalmers Mfg. Co., in cooperation with the Arthur G. McKee Co., Cleveland, was presented by G. V. Woody, manager of Allis-Chalmers processing machinery department.

The report was presented at the January meeting of the American Institute of Mining and Metallurgical Engineers in Duluth, Minn. It stated that the pilot plant was completed, and two runs, one for 2 hr and one for 7 hr, were made. The work the report covered was originally announced at the Blast Furnace Coke Oven, and Raw Materials Conference of the AIME.

Report High-Grade Calif. Asbestos Found

A deposit of more than one million tons of asbestos, in addition to titanium and other materials, in San Bernadino County, 18 miles from Victorville, Calif., was reported by Conda Properties.

The firm said that a report by Ralph S. Willard, of the Hollywood Testing Laboratories on samples of asbestos submitted by Conda Properties stated that the samples "are the finest . . . I have ever seen. The quality is as good as any found anywhere in the world."

L. E. Town, director of Conda Properties, said the firm plans to form a $5 million corporation to exploit these deposits, and set up plants and equipment for processing asbestos, titanium, and other kindred materials. Mining will be open pit.

Copper Ceiling Removal Bid Vetoed by Gov't.

A request for suspension of the copper price ceiling or an increase in the current 24½-cents-per-lb ceiling has been turned down by the Government. The action was announced by Michael DiSalle, Economic Stabilizer under the outgoing administration.

DiSalle said:

"In view of the continuing critical shortage of this basic material, suspension of ceilings is out of the question, and in view of the favorable current earnings position of the industry, no increase in ceiling prices is justified. The present ceilings have been found to be fair and equitable,

enabling producers to achieve a highly favorable earnings position and maintain a continuing high level of production."

He added, "In those few instances where higher prices are required to enable producers to work marginal mines profitably, the Defense Materials Procurement Agency will continue to negotiate special contracts providing incentive payments."

Sulphur Output Capacity Advances 900,000 Tons

Sulphur production has jumped a reported 900,000 long tons per year of new productive capacity since January 1, representing increases brought about by 28 projects in eight nations of the free world.

The U. S. ranks first with 16 projects for an estimated production of about 700,000 tons. Canada is second with five for approximately 84,000 tons, while Mexico ranks third with two for 13,000 tons. Single projects are being carried on in Norway, 75,000 tons; Sweden, 14,000 tons; Ecuador, 10,000 tons; England, 10,000 tons; and Austria, 5000 tons.

The 28 projects are contained in a list of more than 90 tabulated by Freeport Sulphur Co. It is estimated that the combined efforts of these projects will result in an additional 4 million long tons of sulphur in all forms by the end of 1955.

Early Figures Show Coal Safety Record

Bituminous coal mining had what has been called its safest year in history during 1952, with only 0.82 deaths per million man-hr worked, according to preliminary figures released by the U. S. Bureau of Mines.

J. J. Forbes, director of the Bureau, noted that coal mine fatalities have shown a downward trend since 1940 when there were 1.85 deaths per every million man-hr worked, more than double last year's rate. In tabulating the figure, the bureau classifies as a disaster an accident in which five or more persons are killed. There were only two such accidents in coal mines in 1952, accounting for a total of 11 deaths.

Credit was given to operators, state mining officials, and mine workmen for their share in the safety record. Forbes, however, warned against complacency or relying upon legislation as a cure-all.

Report Canadian Potash Discovery by New Devon

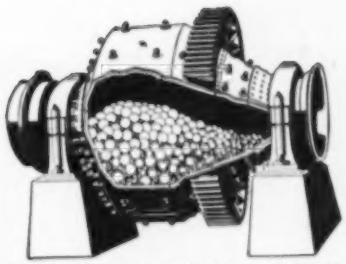
What may be an important potash discovery in the Palo area of Saskatchewan has been announced by New Devon Petroleum, Ltd., on property the firm has an interest.

Heavy gravity oil was discovered in Lower Cretaceous Horizon during a well-drilling operation. Cores from a deeper drilling disclosed potash at about 3800 ft.

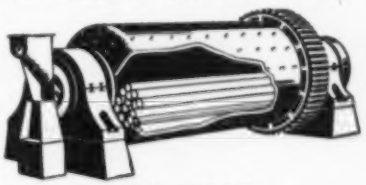
NEW SULPHUR PROJECTS WHICH BEGAN PRODUCTION IN 1952

Source	Company	Location	Capacity (Long Tons)
Brimstone			
Frasch Process	Freeport Sulphur Co.	Bay Ste. Elaine, La.	100,000
	Texas Gulf Sulphur Co.	Spindletop, Texas	400,000
Surface Deposits	Chemical Corp. of America	Sulphurdale, Utah	10,000
	Chemical Plants Corp.	Tixan, Ecuador	10,000
Sour Natural Gas	Gulf Oil Co.	Waddell, Texas	7,000
	Mathieson Chem. Co.	Stamps, Ark.	21,000*
	Odessa-Sid Richardson	Odessa, Texas	7,000
	Petroleos Mexicanos	Poza Rica, Mexico	10,000*
	Phillips Chem. Co.	Crane, Texas	17,500
	Phillips Chem. Co.	Goldsmith, Texas	44,000
	Royalite Oil Co.	Turner Valley, Canada	10,000
	Shell Oil Co.	Jumping Pound, Canada	10,000
	Stanolind Oil & Gas Co.	Slaughter, Texas	14,000
	Warren Petroleum Corp.	Monument, N. Mex.	5,200
Refinery Gas	Consolidated Chemical Ind. Inc.	Baton Rouge, La.	14,000
	Hancock Chem. Co.	Los Angeles, Calif.	17,500*
	J. L. Parker	Madill, Okla.	3,500
	Shell Chemical Co.	Houston, Texas	13,000
	Shell Oil Co., Ltd.	Stanlow, England	10,000
	Sinclair Refining Co.	Marcus Hook, Pa.	7,000
	Standard Oil Co. (Ind.)	Whiting, Ind.	19,200
	Swedish Shale Oil Co.	Kvarntorp, Sweden	14,000*
Other Sulphur			
Pyrites	Normetal Mining Corp.	Dupuy, Que., Canada	4,500
	Electro Kjemisk	Skorovass, Norway	75,000
Smelter Gases	Aluminum Co. of Can., Ltd.	Arvida, Que., Canada	18,900
	American Smelting & Refining Co.	San Luis Potosi, Mexico	3,000
	Bleiberg Mining Union, Ltd.	Carynthia, Austria	5,000
	Canadian Industries, Ltd.	Copper Cliff, Ont., Canada	40,000
		TOTAL NEW CAPACITY	910,300

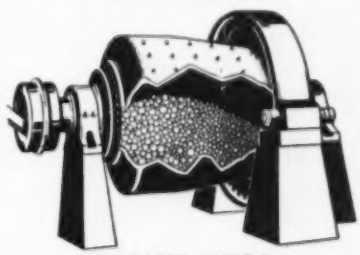
* Added capacity to an already existing plant.



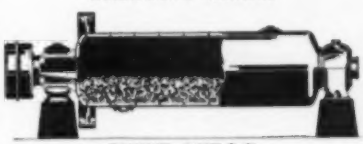
HARDINGE CONICAL MILLS



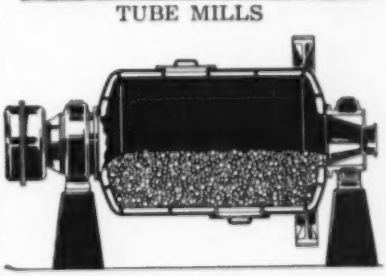
ROD MILLS



TRICONE MILLS



TUBE MILLS



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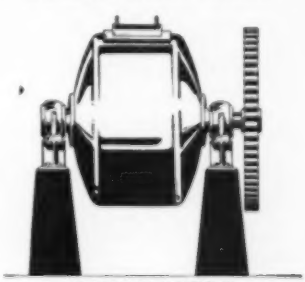

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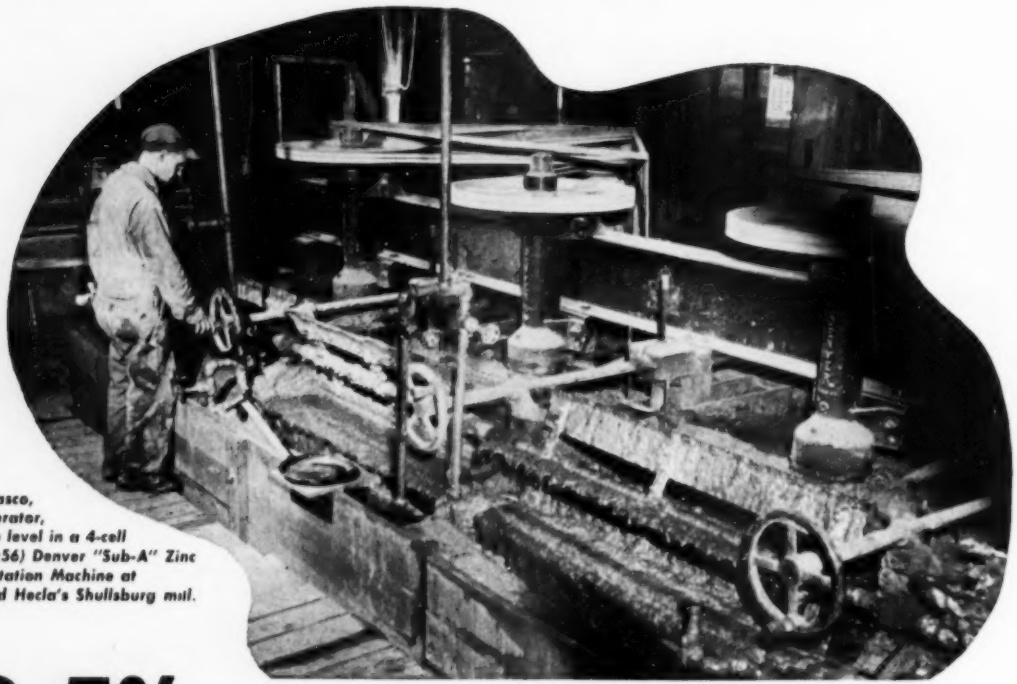

Thomas E. Pasco, flotation operator, adjusts pulp level in a 4-cell No. 30 (56x56) Denver "Sub-A" Zinc Rougher Flotation Machine at Calumet and Hecla's Shullsburg mill.

63.5% Grade Zinc Produced By Denver "Sub-A" Makes GREATER PROFITS for Calumet & Hecla...

Calumet and Hecla Consolidated Copper Company, Shullsburg, Wisconsin, gets a 63.5% Grade Zinc by using Denver "Sub-A" Flotation Machines for *roughing and cleaning*. This premium grade concentrate means greater profit.

You can profit too,—get the complete story of Calumet and Hecla Consolidated Copper Company, Shullsburg plant by writing for the May-June 1951 issue of DECO TREFOIL!

Calumet and Hecla's success is more proof of the additional profits you get with Denver "Sub-A" Flotation Machines. Denver "Sub-A" has become the world leader in flotation recovery because these standard machines have the flexibility it takes to meet changing ore conditions. This flexibility gives your flotation engineer the tools he needs to get the results that pay greatest profits to you.

Write, wire or phone for information on how you can get more from your ore with Denver "Sub-A", as Calumet and Hecla has done.

Denver "Sub-A" Zinc Flotation

Heads	9.49% Zn
Recovery (flotation)	91.00%
Grade	63.50% Zn
Tails	0.20% Zn
Tonnage (concentrator feed)	1200 Ton/24 hr.

COMPLETE MILL EQUIPMENT...from testing to feeder to dryer

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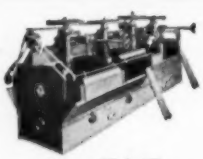

Denver "Sub-A" Flotation Machine

Denver SRL Pumps

Our 25th Year of Flotation Engineering

DENVER EQUIPMENT COMPANY . 1418 17th Street • Denver 17, Colorado

Ten Metals Still On Critical List

Only 11 materials remain on the critical list, with 10 of them metals, according to the Defense Production Administration. One year ago, there were 24 materials on the critical list.

The new list included titanium, cobalt, columbium, molybdenum, nickel, tantalum, nickel-bearing stainless steel, diamond bort, castings weighing more than 3000 lb of gray iron, gray iron alloy, and carbon steel.

Within the last year these items were dropped from the list:

Aluminum, beryllium, selenium, platinum, copper, lead, tin, zinc, tungsten, cold-drawn and hot rolled alloy steel castings, steel plates, and steel structural shapes.

While lead and zinc have been controlled, aluminum and copper remain under government allocation, although shown on the availability list in approximate balance with existing demand.

Beryllium for Civilian Use Shows Increase

A marked increase was noted in 1952 in the quantity of beryl ore available for commercial use in beryllium alloys and products, according to Lawrence P. Boland, sales manager of the Beryllium Corp.

"As compared to the situation existing a year ago, the pressure of military demand for beryllium alloys is considerably relaxed. It is therefore expected that any limitations on civilian applications will be defined by restrictions on the principal base metals with which beryllium is alloyed, namely, copper and aluminum. An easing of controls on these two metals has already been noted, and may very well mark the beginning of a trend."

Boland also reported that new deposits of the mineral are being worked in the U. S. and abroad. Additional known reserves have been established through world-wide geological surveys. "Accomplishments to date indicate that present and future supplies will support continued expansion of industrial usage of beryllium."

DMPA Negotiating for Mexican Manganese

Negotiations are on with several mining companies for production of enough manganese ore from Mexico to justify construction of a processing plant at El Paso, Texas, according to the Defense Materials Procurement Agency.

DMPA wants contracts for half a million tons of low grade manganese ore and a mill operator to build a plant for conversion to manganese concentrate.

A contract has been signed with Mangaslag, Inc., of Ft. Worth, Texas, for construction of a pilot plant for recovery of ferromanganese from open hearth steel slag at Coxton, Luzerne County, Pa. The plant is scheduled for operation within a year and is expected to produce at least 1000 tons of ferromanganese per month, to be sold either to industry or the government. If the process proves a success in pilot operations, Mangaslag will build several commercial plants at its own expense.

Mines Bureau Studies New Blasting Methods

A U. S. Bureau of Mines official reviewed recent research in blasting techniques to the 14th Annual Mining Symposium sponsored by the University of Minnesota's Center for Continuation Study.

Fred D. Wright, Bureau mining engineer with the Eastern Experiment Station, College Park, Md., said current investigation at Pittsburgh has been centered around multiple-hole blasting in coal mines. The Bureau is also studying use of liquid oxygen explosives at Pittsburgh in an attempt to increase safety and keep blasting properties.

A Cost-cutting team

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AND ITS SUBSIDIARY COMPANY COLORADO IRON WORKS
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FLUCTUATING markets, crippling strikes, and various other vicissitudes cropped up last year, but the metals and mining industries met the demands of an ever accelerating defense program. Faced with supplying materials for a dual economy, new equipment, expansion and technological advances were brought to bear.

The steel strike, shutting the nation's mills for weeks, came the closest to actual catastrophe. But even here, once the strike was settled, the mills made a phenomenal return to activity. Capacity was increased, and while the year's goal was not reached, production moved forward at a breathtaking pace. One of the outstanding achievements in the industry took place after the strike, when Lake ore boats moved almost 75 million tons of ore, halting the necessity of extensive rail shipments this winter.

The strike was the last battle for Philip Murray, late president of the CIO and its United Steel Workers Union. He died last fall. Walter Reuther, of the UAW, is now president.

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MINING was probably the hardest hit by the engineering shortage. Predictions for the future were on the pessimistic side, with many young men who ordinarily would have gone into mining seeking other fields. Graduation classes for this year will be even smaller than those of last year. In addition, the controversy over the type of training the young engineer should receive during his school years grew in intensity. A plea was made for substantial improvement in the course of study by the Committee on Adequacy and Standards of Engineering Education. The committee stated that engineering as an art rather than a science was being taught all too prevalently. Demands to teach the whole man were heard. The problem of turning out engineers and at the same time giving them knowledge of the world around them remained for the most part unsolved. The five year program was widely discussed and applied at some schools.

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A VOICE for the minerals industry in top level government seemed closer last year, when Rep. Walter S. Baring (Dem., Nev.) proposed HR 5964, which would establish a Minerals Department and add a new member to the cabinet. Thus far, nothing has come of the move, but some mining men felt that at least it indicated some interest has been generated in the situation. Few people outside of mining realize that there are two basic industries in the world, mining and agriculture. The farmer is represented but the miner is not at the White House. He must take various means to make himself heard, and by the time his voice is channeled up through the chains of command and jurisdiction it emerges rather weakly, as if from some great distance.

With the appointment of George Humphrey to President Eisenhower's cabinet, however, even if no Minerals Department has been established, mining will have some voice in the higher echelons. He is a man who has been associated with mining and its problems for many years. Certainly when mining problems fall into orbit, a keener grasp of the situation than heretofore existed, can be expected.

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THE coal mining industry got the Nealy Mine Safety law in 1952, and for the most part, reaction to it was divided between a philosophy of waiting for results and one which says legislation cannot stop mine accidents, only mine workers can. Harry Truman signed the bill but not without criticism. He felt it should be much stronger. Many of the men working in the mines felt that the best safety bet available was recognition by mine workers that they were the guardians of their own safety as well as that of the men who worked with them. It was a truism long known to miners. The law resulted in a few mine closings, but its usefulness has not as yet been fully tested.

It was a hard year economically speaking, for coal operators. The price of coal was at a low level, and John L. Lewis and his United Mine Workers added to the general cup of woe. After a strike which failed to disrupt much of anything because of huge coal reserves already above ground, the miners and operators reached an agreement. The additional $1.90 was turned down by the wage stabilization board and later approved. The agreement between the Northern Coal Operators and the union worked to drive a deeper wedge between the operator's group and some mid-western state associations.

Light appeared on the horizon, however. Some experts saw increased use of coal in the future, while certain research projects started to show results.

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ALCOA plans to build an Aluminum industry in Alaska created a sensation in the U. S. and in Alaska—but something less than that in Canada. The project would require Canadian water power. Canada is in the process of building its own aluminum industry. At first, a ready agreement seemed in the making, but protests from various factions in Canada arose. At this point, it doesn't seem likely that plans will go through as projected—not for a time at least.

Aluminum production expanded considerably, with Canada going full steam. Aluminum Ltd., through its wholly-owned French subsidiary, Bauxites Du Midi started bauxite mining in the Island of Kass, in French West Africa. The shipping schedule called for about 10,000 tons every 10 days.

In the United States, expansion went ahead rapidly, with several plants completed, under construction or rapidly climbing out of the planning stage. The water power shortage posed a threat to the industry, and in several areas operations were severely hampered.

TENDENCIES toward nationalization grew noticeably stronger in some areas. Late last fall Bolivia took over the tin mines of four foreign operators and handed them a bill for a fabulous amount claimed for damages. In the same breath, the price Bolivia offered to pay for the mines appeared to many to be slightly ridiculous. Many engineers felt that the country would not be able to run the mines successfully. Even if they could, some thought that the Bolivian Government would gut the orebodies in an attempt to get at rich deposits for high profits, leaving the lean ores in unmineable condition.

Bolivia has a definite dearth of native technical men. Foreign engineers are leaving, or preparing to leave the country. The Bolivian ambassador, in several statements to the press and other groups, said that his country welcomed foreign investment. He charged that the former operators of the tin mines had been working to the detriment of his country.

In the meantime, feeling among stockholders was that companies had depended entirely too much on the good will of the nation. They felt that profits put back into the mines for improvements should have been declared as dividends. Other nations appear to be considering nationalization, with many of them openly expressing the opinion that payment need not be made to former owners.

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FREE world production of nickel approximated 315 million lb in 1952, according to John F. Thompson, chairman of the board of International Nickel Co., with Canada producing about 90 pct of the total. Free world production was estimated at about five times that of the rest of the world. Thompson voiced the opinion that the nickel situation is still not healthy enough to supply large government stockpile requirements simultaneously with unrestricted use in the civilian economy and defense programs. However, nickel allocations made by the International Materials Conference have been in excess of defense requirements and nickel has been available for civilian consumption to some extent.

Much has yet to be accomplished before a satisfactory state is reached. Exploration is going on at an unprecedented rate, with several new companies involved. Most of the work is being financed by private capital, Thompson said. Some of it, however, is financed by the U. S. and other governments. Inco, Falconbridge Nickel Mines, Ltd., Sherrit Gordon Mines, Ltd., Nicaro, and the French firm of S. A. Le Nickel have been engaged in expansion programs.

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IF the price level can be protected, American lead mine operators can look forward to a satisfactory year in 1953, according to Andrew Fletcher, president of St. Joseph Lead Co. However, he termed as "inept" Government efforts in 1952 to stabilize the market for an international commodity. He pointed out that the Government had created an artificial shortage of the metal at the outbreak of the Korean war by establishing ceiling prices for lead and zinc, a procedure not followed by other countries. Lead, meanwhile, according to the St. Joseph president, and President of AIME for 1953, accumulated in European markets. When Great Britain sold some 60,000 tons of lead from her surplus to the U. S. for stockpiling, and the advent of the free offering of lead with the opening of the London Metal Exchange in 1952, the foreign price dropped to about 10¢ a lb and U. S. market declined from 16¢ to 13.5¢.

When the foreign market improved in December, some advance in the U. S. price was noted. U. S. consumption of lead in 1952 reached approximately 12 million tons. Domestic production reached 375,000 tons, a slight drop from the mark reached in 1951. Imports increased sharply to 535,000 tons, more than double the 258,000 tons in 1951. Scrap reclamation declined somewhat to 440,000 tons.

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COMMERCIAL taconite production, discussed endlessly in technical journals, seminars, and on panels, may be a reality by 1955 as the result of a $148 million loan made to Reserve Mining Co. Borrowed privately from major life insurance companies, the money will go into plant construction at Babbit and Beaver Bay, Minn. Total cost of the project has been estimated at about $160 million. Reserve's taconite deposits cover about 10,000 acres near Babbit. Remainder of the financing is expected to come from Republic Steel Corp. and Armco Steel Corp., joint owners of Reserve.

Content of the ore concentrate to be shipped is expected to run more than 60 pct iron, higher than the percentage customarily shipped from the Mesabi Range. Construction of the plant is scheduled for completion by June, 1957, but ore shipments may leave Beaver Bay by 1955. The project will include an interplant railroad, a secondary crushing plant, a harbor, docks, ore boat loading equipment, and a 55,000 kw power plant located at Beaver Bay on Lake Superior.

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INCREASED demands for minerals and fuels have caused a great surge in geophysical investigation. Replacement of depleted ore reserves and discovery of new orebodies have been aided by the airborne magnetometer.

Mechanization in mines has continued to make great progress. Climbing costs and decreasing prices have given impetus to modern methods of mining. Belt conveyors became even more significant as new material handling methods were sought for both mill and mine.

Easing in supply of some minerals which were on the critical list was noted. Among them were fluorspar and sulphur. Important new production of asbestos, lithium and rare earths also helped.

At the start of the year free world position in respect to manganese was at best not too good. But as the facts began to emerge, the absence of Russian manganese became less important. At the end of the year the West could feel a lot easier as production outside of the Russian zone of influence showed definite signs of making up for the loss.

FAGERGREN'S INCREASED FLOTATION RECOVERY PROVED BY COMPARATIVE TESTS

TEST DATA

These are actual results of an extensive test program recently concluded by a progressive mining company seeking to determine the best all around flotation machines to be installed in their plant. The tests conclusively proved Fagergren superiority in terms of *lower tailing losses, higher concentrate grade, lower reagent costs,* and *lower smelting charges.* These added up to a substantial dollars and cents advantage in both metal and overall recoveries.

The increased metal and economic recovery of the Fagergrens is shown in cents per ton of mill heads. Cell volume ratios are total cubic feet of cell volume in the Fagergren test machines versus cubic feet in competing machines handling the same feed rate.

CELL VOLUME RATIOS (Fagergrens to competing units)	METAL RECOVERY (Fagergrens over competing units)	ECONOMIC RECOVERY (Fagergrens over competing units)
1 to 1.8	+ 2c ton	+ 2½c ton
1 to 1.66	+ 2⅔c ton	+ 3c ton
1 to 1.07	+ 6⅔c ton	+ 6c ton

Proof that higher speed of float pays off

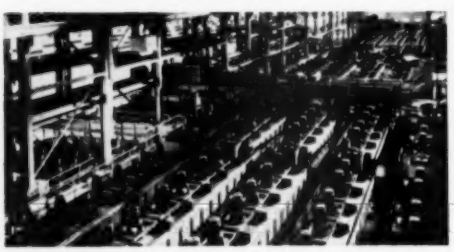
These tests and other related data conclusively demonstrate that Fagergrens achieve higher recovery with less cell volume. Note that even with 80% more cell volume, the other machines could not match the recovery of the Fagergrens. Furthermore as the ratio of cell volumes was reduced, the Fagergrens' margin of recovery increased still further.

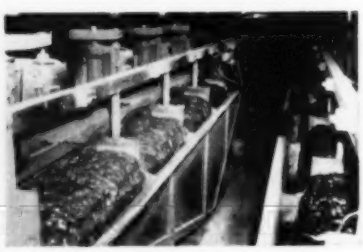
Greater throughput capacity per cubic foot is the direct result of the faster rate of flotation achieved by Fagergren's exclusive rotor-stator principle. This powerful agitating mechanism provides an unmatched efficiency of pulp aeration and dispersion.

To the Fagergren's gains in metal and economic recovery shown in the above data, the fact that fewer cubic feet of machine are required adds these further savings — lower installation costs, reduced floor space, less operating labor, etc.

WRITE TODAY for consultation on your specific flotation problems and for free descriptive literature on Fagergren machines.

Typical installations of Fagergren Flotation Machines.





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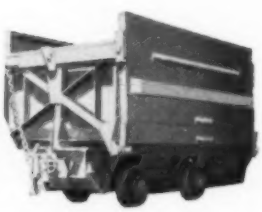
THAT'S what this Lake Shore Man Haul car (above) gives 30 men . . . a dry, safe, comfortable, upright ride with plenty of knee and headroom — space on the seats for dinner boxes. Enclosed design gives men full protection. Available insulated against electricity. Car equipped with full universal oscillating trucks, or conventional type.



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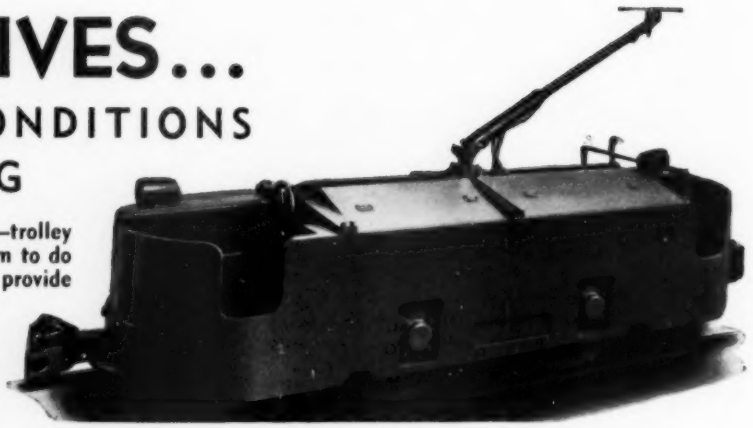
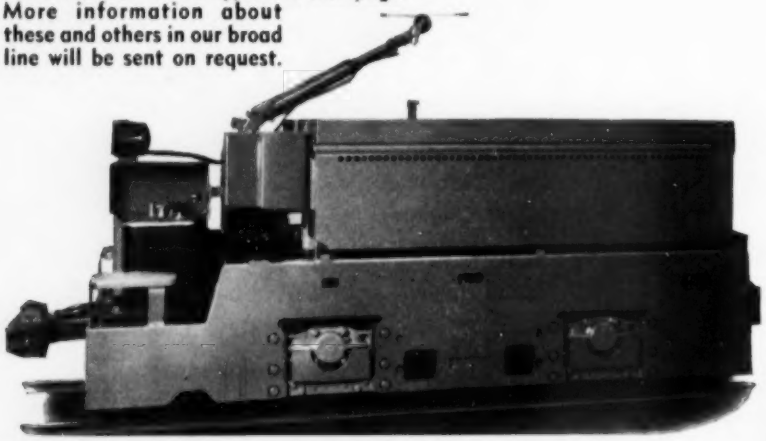
Haulage, gathering or trammer locomotives with all the features that over fifty-five years of study can possibly put into them. Experience is still a good teacher and Jeffrey Engineers have an ample supply of that as evidenced by hundreds of successful installations.

For haulage and tramming in the Metal Mine we show three types on this page. More information about these and others in our broad line will be sent on request.

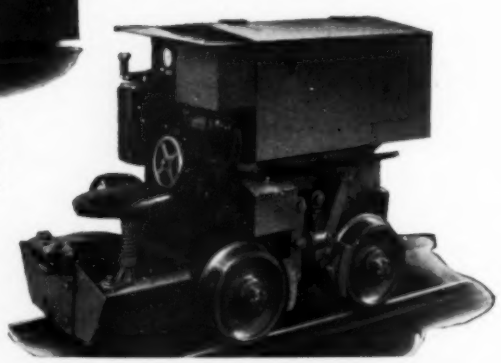


Jeffrey 6-ton, round-end Trolley Locomotive with two 30 H. P. motors. 24" gauge; 33" wheels; 54" height with trolley pole locked down; length is 13'8"; width 46" and wheel base 48". This is a neat, compact job for handling your haulage operations.



Jeffrey Storage Battery Locomotive — 12,000 pound chassis and 30" gauge. Two 30 H. P. motors—two-rate battery charging from trolley—60" high with trolley locked down; wheel base 56"; length 7'2"; width 52". This combination trolley and storage battery locomotive will give you years of service under the severest conditions.

The Jeffrey Trammer (below) is a 1½-Ton compact unit—can be arranged for trolley, storage battery or cable reel operation. Has a 6 H. P. motor; short wheel base (only 26") to take sharp curves; compact construction to meet gauges down to a minimum of 18"; water tight construction; operator's deck can be removed to shorten length for entering cage.



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Shuttle Cars
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MINING, MATERIAL HANDLING AND PROCESSING EQUIPMENT

Drift of Things

WHEN asked a few weeks ago if we wished to visit the Coors plant at Golden, Colo., we agreed with alacrity being well acquainted with the high quality of Coors beer and having heard that the company was most liberal about sampling privileges. Instead of a brewery, we found ourselves in a pottery, the Coors Porcelain Co., owned and operated by the firm of beer fame. Our apparent disappointment was dispelled as the wonders of the porcelain products were unfolded.

Until this visit we had always thought of porcelain as fragile, used for bathroom vessels, dental fillings, or tableware; instead we found a whole variety of uses where metals had left off and ceramics had taken over. Our guide hefted a 2½ in. diam porcelain ball in his hand and then threw it on the floor catching it on the return bounce; the ball was not even chipped. Depending on the composition of the porcelain (alumina is a basic ingredient) products can be made with tensile strength up to 27,000 psi, compressive strength 290,000 psi, modulus of rupture 50,000 psi, modulus of elasticity 40,200,000 psi. In the extra-high strength ceramic a specific gravity of 3.57 and hardness of 9+ is attained. Products made from it are nonporous and refractory. For instance at 800°C the thermal conductivity is 29 Btu per hr per sq ft per °Fahrenheit per in.; the thermal coefficient of expansion between 25° and 1000°F averaging 9.14×10^{-6} per °C. Working temperature in the extra high strength ceramic is quoted at 1700°C maximum. Generally speaking this alumina porcelain is resistant to abrasion and corrosion even at high temperatures, is nonporous, and has a high dielectric constant.

Except for the grinding balls which come either in round or natural shape and are used for grinding in the paint, porcelain enameling, ceramics, and cement industries, the other products are designed to order. Such products as pipe and pump liners, bearing sleeves, and high refractory jet engine parts are made to name a few. The property of long-wear coupled with strength under high temperature or corrosive chemical conditions offers a multitude of possibilities for use.

Each order usually requires a tailor-made production setup. Since the porcelain cannot be machined to the close tolerances of steel, these limitations must be established. A mold is made for a basic shape from which the final product shape may be machined. In production, the porcelain powder compound is placed in a mold and subjected to high pressures; no heat is applied at this stage. The basic form is then put on a lathe, held by a vacuum chuck, and machined to specification. The raw product is then fired at about 2900°F. Thin structures, or those with sharp corners, can of course be chipped.

This type of porcelain manufacture stems from the spark plug manufacturers. The basic clay compound used is a craft secret. Those working with the high-density alumina ceramic are finding new and surprising uses as manufacturers send in their problems. Our only suggestion to date has been high density porcelain nursing bottles.

AUTHORS of the Third Annual Review issue of MINING ENGINEERING have correlated information for each article from sources too numerous to credit individually. For one article 75 correspondents in industry, government and education helped supply the world-wide picture. A thick folder was filled by carbon copies of letters requesting or verifying data for another article. At this point we wish to join the authors in acknowledgment of the splendid cooperation that made this venture possible for MINING ENGINEERING. And, the editors wish to express their debt for the top notch job done by the authors themselves in preparing the review.

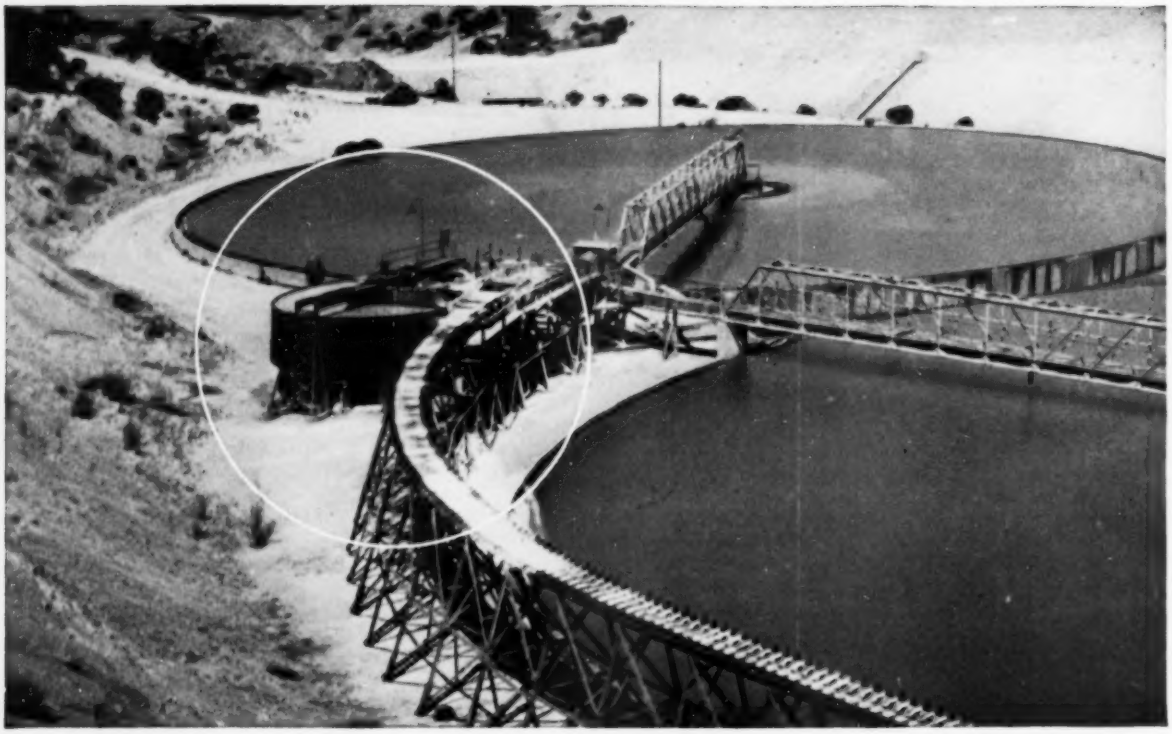
COMFORTING news has been received from the United Nations. The world has enough iron ore reserves to make 84 billion net tons of iron, which is computed to be enough to last 825 years at the current rate of consumption. On the same basis the report discloses 1.1 billion tons of manganese (50 pct Mn), enough for 250 years; 6.6 million tons of recoverable tin, 38 years supply; and chromite and tungsten in sufficient quantity for 47 and 125 years, respectively. On the all-important question of distribution the report points out that 47 pct of the iron ore reserves, 5 pct of the manganese, and 8 pct of the tin are in the Western Hemisphere. Nothing of course about company reserves distribution.

We imparted this information to Frank Sisco on the elevator and he took his pipe out of his mouth long enough to remark: "things haven't changed a bit I see, still arguing over resources." He went on to point out how nebulous reserve estimates on such a large scale were, expanding and contracting depending on who does the figuring.

This is not the first time the United Nations has shown an interest in world resource problems. In August 1949 a world resource conference at UN headquarters, then at Lake Success, gathered some of the world's leading scientists and engineers. In one particular session, which like the others was a melting pot of nations, the prodigality of the human race towards its natural resources became the paramount issue. A United States delegate deplored some of the extravagances of our high standard of living. This was greeted by approval from some of the Socialistic nations. When the Chairman of the meeting asked the U. S. delegate if he would recommend conservation in consumption, a rather delicate situation was created. The U. S. delegate, no doubt thinking of the bureaucratic ramifications of such a proposal, thought not.

On this particular day one Paul Foote, Gulf Research & Development Corp., supplied the answer which we like to use whenever the occasion arises. Speaking up boldly like a sturdy son of the free enterprise system he said in effect: "I will live prodigally, if that is what you call it, having confidence in the ingenuity of my fellow engineers and scientists to supply new ways of doing things with new materials as the old ones are exhausted."

John V. Beall



Smooth out your tailings operations

in spite of increased tonnage . . . changing ore characteristics

Here is how one operator solved the problem of increased tonnage and changing ore characteristics . . . with a Dorr Hydroseparator.

To handle a total of 12,000 tpd of copper flotation tailings at 26% solids, the initial installation included two Dorr Torq* Thickeners, each 225 ft. dia. When variables in ore characteristics reduced thickener capacity and increased water loss in the underflow, a Dorr Hydroseparator was installed ahead of the thickeners to compensate for shock loads. The Hydroseparator installation, resulting in better thickener performance, did two things:

1. Mill output *increased* by an average of 1,000 tons per working day.
2. The amount of water lost in thickener underflow *decreased* by 166 gpm.

The Summary of Operating Data shown here gives additional information, before and after the installation of the Dorr Hydroseparator.

To solve your tailings thickening problems, make use of our diversified experience in the field of metallurgical production. Let us know about your problems and we will work to solve them with you. THE DORR COMPANY, Barry Place, Stamford, Conn.

*Reg. U.S. Pat. Off.

Dorr Hydroseparator
Summary of Operating Data
Castle Dome Copper Co., Miami, Arizona

Year	Feed to System Avg. Tons Per Day	Character of Feed	Percent Solids Combined Underflow
	WITHOUT HYDROSEPARATOR		
1948 (Jan.-June)	10,406	Hard Ore	44.5
Dorr Hydroseparator Installed July 1948			
	WITH HYDROSEPARATOR		
1948 (Aug.-Dec.)	11,436	Hard Ore	45.2
1949	11,814	Variable Ore	46.4
1950	11,905	Variable Ore	47.8
1951	12,076	Variable Ore	47.9

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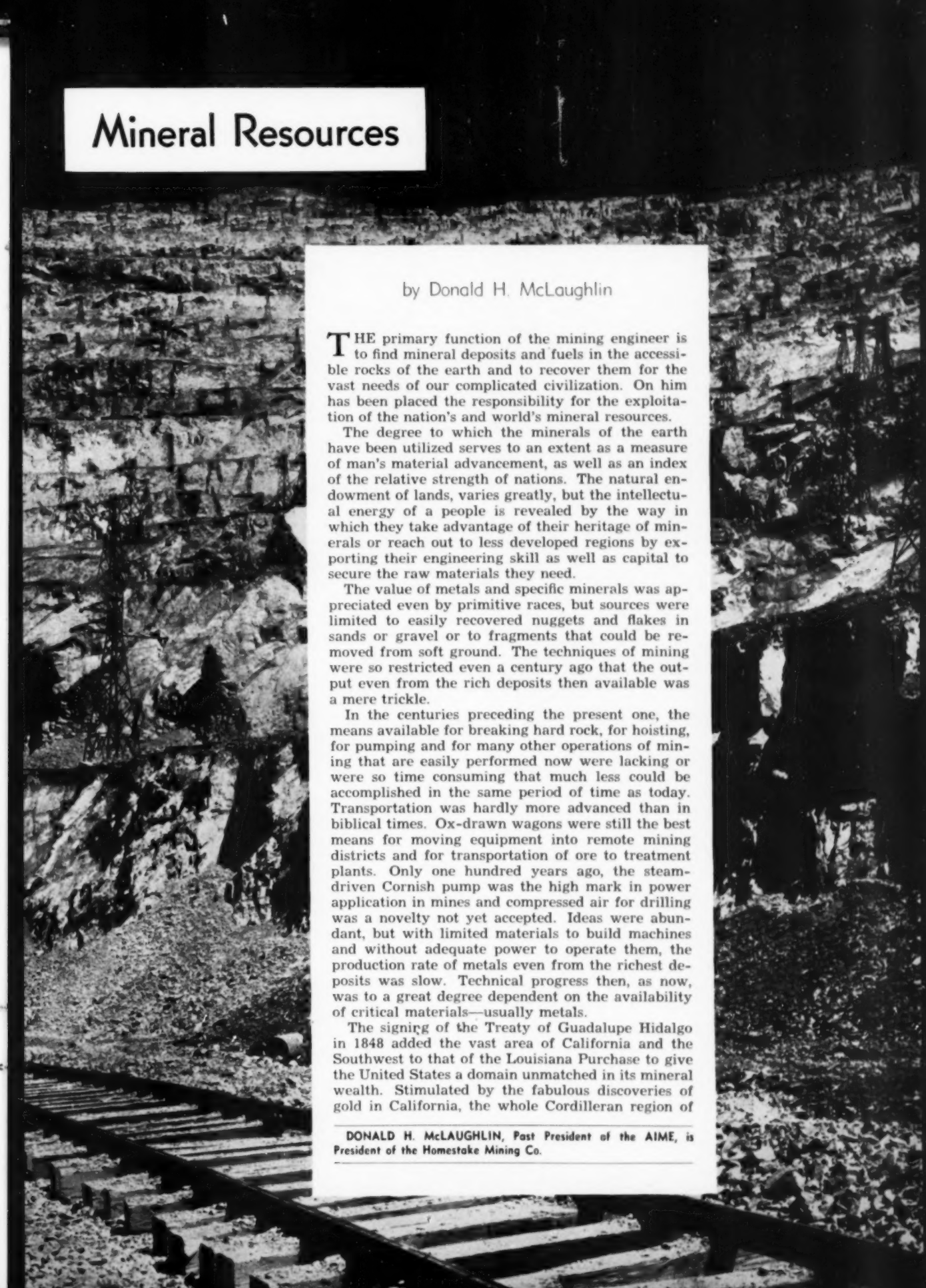
Mineral Resources



by Donald H. McLaughlin

THE primary function of the mining engineer is to find mineral deposits and fuels in the accessible rocks of the earth and to recover them for the vast needs of our complicated civilization. On him has been placed the responsibility for the exploitation of the nation's and world's mineral resources.

The degree to which the minerals of the earth have been utilized serves to an extent as a measure of man's material advancement, as well as an index of the relative strength of nations. The natural endowment of lands, varies greatly, but the intellectual energy of a people is revealed by the way in which they take advantage of their heritage of minerals or reach out to less developed regions by exporting their engineering skill as well as capital to secure the raw materials they need.

The value of metals and specific minerals was appreciated even by primitive races, but sources were limited to easily recovered nuggets and flakes in sands or gravel or to fragments that could be removed from soft ground. The techniques of mining were so restricted even a century ago that the output even from the rich deposits then available was a mere trickle.

In the centuries preceding the present one, the means available for breaking hard rock, for hoisting, for pumping and for many other operations of mining that are easily performed now were lacking or were so time consuming that much less could be accomplished in the same period of time as today. Transportation was hardly more advanced than in biblical times. Ox-drawn wagons were still the best means for moving equipment into remote mining districts and for transportation of ore to treatment plants. Only one hundred years ago, the steam-driven Cornish pump was the high mark in power application in mines and compressed air for drilling was a novelty not yet accepted. Ideas were abundant, but with limited materials to build machines and without adequate power to operate them, the production rate of metals even from the richest deposits was slow. Technical progress then, as now, was to a great degree dependent on the availability of critical materials—usually metals.

The signing of the Treaty of Guadalupe Hidalgo in 1848 added the vast area of California and the Southwest to that of the Louisiana Purchase to give the United States a domain unmatched in its mineral wealth. Stimulated by the fabulous discoveries of gold in California, the whole Cordilleran region of

DONALD H. McLAUGHLIN, Past President of the AIME, is President of the Homestake Mining Co.

On the occasion of the Centennial of Engineering Dr. McLaughlin sketches the to meet the vast needs of our complicated civilization

the continent was explored so thoroughly that in the next fifty years scarcely a half dozen of the important mining districts now known escaped discovery. Those missed were principally deposits of molybdenum, vanadium, tungsten, as well as nonmetallics such as potash, and fluorite, whose value had not then been recognized. Exploitation of the lead deposits of the Mississippi and copper in the Lake Superior region, along with the zinc of Franklin Furnace, had started sooner, but the energetic development of the ore deposits accompanied rather than preceded the opening of the West.

First Surge in Mining

Great discoveries resulted in a burst of activity, coinciding with the construction of railroads and with growing skill in mechanical techniques needed for the operation of mines. The excitement aroused by California gold had scarcely declined before the bonanza of the Comstock attracted attention to deposits of a different type and in different terrane. The finding of copper ores in the Southwest and at Butte, of lead and silver in the Coeur d'Alenes, at Leadville, of gold in the Black Hills and in other major districts of the West was the dominant factor in the opening of the Cordilleran province. These discoveries provided the incentive for bold application of the engineering of the times. The men of those days who combined skill with the endurance and courage to face deserts and mountains not only had opportunity to win rich rewards but also to keep their gains. Metals were provided in abundance and technical uses of them multiplied.

The rich deposits, naturally, attracted attention and were the first to be exploited. Such deposits, however, are limited in quantity. They are end products of long continued geological processes that in peculiarly effective ways brought about extraordinary concentrations of an element or elements in a restricted environment.

From the bonanza ores that were rapidly exploited by the first wave of miners came the first quick wealth. With increasing skill and with better facilities, the grade of ore that could be profitably treated was lowered. This resulted in enlargement of the tonnage of mineralized material that could be called ore and in lengthening the active lives of the mines and districts.

In this period, acute transportation difficulties were overcome by the many railroads built into some of the roughest terrain on the continents. Without them, few of the major districts would have survived the exhaustion of the first tonnages that alone provided ore rich enough to be worked at the end of mountain trails or of long hauls by ox-cart. The daring loops and rock work of the early grades that were carved through the canyons and across the high passes remain as monuments to the engineers who made remote districts accessible and thereby promoted the growth of famous mining enterprises.

Wood-fired steam boilers were the principal source of power and thousands of acres of timber lands were ruthlessly denuded to supply fuel. As shafts deepened, steam hoists were designed and built that are unrivaled in craftsmanship of their intricate and well-fashioned moving parts. Steam, however, had its limitations and found little use underground, where mechanical progress was slow until the advantages of compressed air were recognized and effective equipment designed for its use. Compressed air, principally in the operation of rock drills for blast holes, gradually won first place as the form of power best suited for underground mining needs. Heavy piston drills replaced hand-held steel and hammer. Recognition came rather slowly for these early machines because of size and weight. Furthermore, they were dangerous dust producers, though the seriousness of the hazard to health was not recognized for some years. To the mining engineering profession is perhaps due some discredit for the slowness with which the techniques of this basic operation were improved and made safe. In spite of its mechanical advantages and the introduction of water to control drilling dust, the hammer drill was only beginning to be generally used in the first decade of the present century.

Stoping methods were varied in the first half of this century as they had to meet the many conditions imposed by the nature of the ground and shape of the ore deposits. Most of the standard practices that are employed today were in use, though with slower procedures in their unit operations. The square-set method was devised to mine the large bodies of rich ore in weak ground on the Comstock Lode in Nevada, at the cost of some of the finest timber on the shores of Lake Tahoe. In the iron country, top slicing with caving of the overlying ground was adapted to American conditions from practices in England. The first attempts to mine by block caving were made in the old iron ranges and basic ideas were demonstrated in this work from which the elaborate caving systems so successful some years later in the porphyry copper deposits were evolved.

Example of the Porphyry Coppers

At the beginning of the Twentieth Century, the second great surge came in mining. This was brought about by D. C. Jackling and those inspired by his demonstration of the profits that could be won from huge masses of low grade disseminated copper ore by bulk mining and concentration. By stripping the leached capping from the massive deposit at Bingham Canyon, Utah, the first porphyry copper mine was created. Ore was removed by an open-pit operation with power shovel loading and

PICTURES FROM THE PAST remind us of the technical progress that enabled mining to keep pace with ever increasing demand, ever depleting deposits.

past and outlines problems to be anticipated by mining in the future as it strives

Problems the industry has vigorously tackled in 1952

standard gage railway transportation from the pit to the mill. The success of this operation attracted attention to similar deposits elsewhere and a succession of new copper producers was created. For those orebodies that were too deep, systems of undercut caving were devised from the methods previously tried with some success in the iron ranges. By utilizing gravity to break large blocks of ore, costs were low enough to win profits from ore almost as lean as that mined in the open cuts. The range of the porphyry coppers was thus extended. These achievements were timely for without them copper would inevitably have become too high in price and inadequate in supply to meet the rising demands in the manufacturing of electrical equipment, then beginning to need this indispensable metal in increasing quantities.

Electricity For Special Mining Needs

Hoisting from deep shafts imposed conditions that required particular ingenuity to meet with electricity as the source of power. The succession of peak loads resulting from the repeated accelerations of a skip filled with ore at the end of a heavy steel rope presented problems in design not easily overcome. The motor-generator sets, heavy fly-wheels and powerful motors at the hoisting plants at our deep mines today are examples of how these requirements were met.

Pumping is another operation in which electrical equipment is performing indispensable service in a number of mines. Removal of water from mines has taxed the ingenuity of engineers in all ages. The woodcuts in Agricola's *De Re Metallica* reveal the concern of the 16th Century miner with this problem. His methods of pumping were limited more by lack of power and materials than by lack of ideas. The first application of the steam engine was to pump water from a mine. The old Cornish pumps with their massive steam cylinders were so successful that a few of these primitive devices remained in use even into modern times. The steam engine itself, however, is practically limited to the surface, and transmission of its power by long rods is cumbersome. The electric motor today is without competition as the power source for mine pumps. Particularly in alignment with multiple centrifugal pumps, it commands the field where heavy work is to be done and has enlarged the range of mining by draining large ore deposits heretofore inaccessible in extremely wet terrain.

Control of water in loose or running ground is of course still a major concern in mining operations. Shafts under such conditions can be sunk, if necessary, with the use of caissons, grouting with cement or by freezing methods. Engineering techniques for sinking through quick sands and the wettest material are well developed, but their range of application in mining is rigidly determined by their cost and the value of the ore made available. When ground of this sort cannot be avoided, it can be handled, but at a cost which raises the grade of ore from which profits can be made, thereby reducing the available reserves.

Enlargement of Ore Supplies Through Metallurgical Advances

Process metallurgists should receive a fair measure of credit for the surge forward in this same period of mining history. Gradual perfection of differential flotation probably deserves first place among achievements in this field for its effects have been of such wide application. It not only provided a better means for concentrating metallic minerals from gangue but also made possible the separation of the ore minerals themselves. By these processes, mixtures that had been too troublesome to treat economically were made to yield simpler products that could be smelted or leached with lower costs and higher recoveries. Complex ores, previously of little value, then became available for the mills and smelters. Dozens of mines became productive. Without differential flotation, the output of lead, zinc, copper, silver and various minor metals would be seriously curtailed today and ore reserves would be notably reduced. Without these advances in the metallurgical field, the world would already be seriously short of these metals and industrial progress would have been seriously handicapped.

Physical metallurgists have also made notable contributions to mining practice. Without the many improvements in special steels, resulting in better winding ropes, more rugged machines and tougher digging blades, to mention only a few items, the mining plant now in service would be far less trustworthy. Steel for rock drills has long been one of the critical materials in mining and many beneficial changes in practice at all stages are to be attributed to the growth in scientific knowledge of its properties that has enabled the operators to do better in both design and use.

In the last few years, improvement in drilling methods, principally for blast holes, has probably attracted more attention in the mining world than any other technical phase of the industry's many operations. For many decades, the art of drilling has advanced slowly as steel and its alloys to meet the special needs of miners were provided, and as better mechanical equipment such as lighter hammer drills and detachable bits displaced the heavy machines and accessories of the past. The sudden advance in recent years, however, has come largely from the use of tungsten carbide alloys for the cutting edges of drill bits. Increased rates of drilling, maintenance of bit gage, simpler sharpening practices, and other factors contributed to the success

of the new devices. Older equipment however has been improved with some degree of success in an effort to hold its own. Detachable bits of various sorts, using conventional steel, have been modified in ways that still keep them in the competitive group under some conditions. Lighter machines put on the market by nearly all the major companies have been designed to take advantage of the properties of the new bits. The benefits to the mining industry from these changes cannot be measured solely by the detailed data of drill performance. More significant considerations are the increases made possible by them in the overall rates of advance of drifts and crosscuts and in tonnages of ore broken per man. In these days when skilled miners are scarce and wages high, the employment of light, easily handled machines brings notable savings that justify good earnings on the part of the miners.

Development on the Iron Ranges

In iron mining, achievements were roughly parallel to those in the mines of the western Cordillera, yet with differences imposed by the special characteristics of the ore bodies themselves. High-grade ore existed in relative abundance. Immense tonnages on the Mesabi were accessible for open-pit operations and in addition there were substantial tonnages of good ore available for extraction in the deep mines. The techniques of both types of mining were carried to a degree of perfection that insured not only cheap mining but clean mining.

Although not alone in the field, the open-pit iron mines are among the foremost in use of heavy equipment for haulage of overburden and ore. The operators have taken full advantage of the development of power shovels and draglines, bulldozers, and belt conveyors. The latter are even competing with hoisting from some shallow mines where large tonnages are moved. The underground iron mines also led the way in the employment of scrapers, an operation which has become widely accepted as standard practice in many other mines. Cost reduction made with this type of horizontal movement of ore has increased the relative advantages of stoping methods in which the ore is removed in successive slices over those in which more use is made of vertical movement through closely spaced raises. A number of major changes in practice have resulted from this improvement in mining practice.

Utilization of tremendous reserves of iron-bearing low-grade material in the Mesabi region has long been recognized as an eventual and necessary development, as high-grade ores were depleted. Before the war, substantial, though somewhat leisurely, progress was being made on the technical problems that would have to be solved before a substantial fraction of the country's iron ore could be recovered at reasonable costs from such sources. The time when these ores would become urgently needed then seemed comfortably remote. The reserves of high-grade ore available in the Mesabi, however, were so heavily drawn upon to meet the increased consumption of the war years and of the period of uneasy peace that now to neglect the development of other supplies would be to invite shortages that could be disastrous in times of emergency. Fields found not too far from our borders undoubtedly will relieve the situation to a notable degree. But, at best, the tonnage from these areas will not fully offset the decline in output of high-grade ore from the major domestic range, and beneficiation of low-grade material must inevitably contribute an increasing part of the total requirements.

Technical problems involved in utilizing the taconite of the Mesabi have been formidable, but the success with which the difficulties have been met make it certain that an important contribution to the iron supply of the nation will soon be forthcoming as concentrates from the magnetite-bearing material of the eastern part of the range.

Conditions to be Anticipated

The danger of shortages of the vital raw material derived from domestic ore deposits does not allow any room for complacency. It is not that they are nearing exhaustion or that the production in the aggregate is beginning to fall off. Indeed, the mines are turning out far more tonnage of ore than they ever have in our history. From an engineering standpoint, this may be a just source of pride. But it must be recognized that the available known and profitable sources of our metals are being depleted at a shocking rate to meet demands that seem to grow without end. The excessive consumption of our minerals is sheer waste to the extent that the products are for war or preparation for war and no less deplorable because it now seems to be a necessity.

To the geologist, shortages of ore deposits are imminent even for the planet as a whole. So-called civilized man is proving to be one of the most active and destructive geologic agents that has afflicted the face of the earth, particularly in his selective attack on the peculiar natural concentrations that are termed mineral deposits. Unless our dependence on minerals is relieved as the result of scientific discoveries or by new technical skills that change the whole pattern of our industrial civilization, the sources relied on today will become extremely scarce within periods that are not long in comparison with the lives of nations. In these days, there is some justification in expecting amazing new developments, but so far the achievements of the nuclear physicists and other high priests of science tend to increase our dependence on minerals rather than to relieve it.

Even the well-endowed continent of North America is showing the strain from the tremendous drain on its mineral deposits. The shortages of certain vital materials, such as tin, manganese, chromium and tungsten have been apparent for many years, but only recently has it been realized that the output of our iron, copper, lead and zinc mines, hugh as it is, must be supplemented with ores and concentrates from outside U. S. boundaries if industrial activities are to be maintained on their present scale. Imports cannot be avoided and for protection against drastic shortages at critical times, large stockpiles of minerals and metals from abroad is no more than ordinary common sense.

In the midst of the lively debate now in progress with regard to mineral supply problems, the following conclusions seem inescapable: (1) the period of abundance of minerals and metals, when the United States had exportable surpluses of most of them, is permanently over; (2) the rate of discovery and development of new orebodies is declining and in all probability will continue to do so; (3) more and more of the domestic production of metals and minerals will have to come from lower grade ores, requiring the expenditure of more man-hours power and/or materials per unit recovered as well as larger

capital investment; (4) the degree of dependence on imports of mineral raw materials will increase; (5) industrial minerals and metals, with a few exceptions, are likely to become more expensive or valuable in terms of other commodities over the decades ahead in spite of temporary reversals and over-production of specific metals at intervals. These conclusions are of course based on the assumption that industrial life of the nation and the world will continue with more or less its present pattern and that the scientific miracles of the times will not bring about drastic simplifications. This assumption seems a safe one, for from all present indications every spectacular advance in scientific knowledge thus far seems to increase rather than decrease the demand for minerals and metals.

A national policy with regard to minerals should be formulated in line with these major considerations. Essential parts of such a policy should be (1) thorough exploration of the nation's potential mineral resources, and wise, economic and efficient exploitation of the known deposits by private enterprise; (2) reliance for incentive on free market prices with a system of taxation that permits retention of profits from successful ventures commensurate with the risks of mining; (3) restriction of government assistance, participation and controls to certain well-defined and limited procedures available uniformly to all.

The activities of the government in the field of the mineral industries should be confined to: (1) scientific and technical research on the part of agencies such as the United States Geological Survey, United States Bureau of Mines, Atomic Energy Commission and the National Science Board; (2) purchase of minerals and metals for a national stockpile as a continuing, steady practice with the objective of creating a depletion reserve as well as providing for national security with purchases increased when world prices sag and curtailed in periods of temporary shortage and high prices; and (3) agreement to purchase certain relatively scarce minerals or metals from domestic mines at stated prices for each metal, the same for all producers, which should be sufficiently high and guaranteed for long enough periods to encourage exploration and development of mining enterprises and to maintain mines in operation that would be adequate to provide some domestic production in the event of loss of vital foreign imports, with assignment of minerals or metals thus purchased to a stockpile and with reliance on imports without tariff for normal industrial needs for such scarce materials.

Improved Exploration Methods Needed

Improvement or enlargement in methods of exploration is mostly emphatically needed to increase the rate of discovery of the concealed deposits from which future ore supplies must come. This involves research to increase our knowledge of the habits of orebodies, so that their geologic relations may be more sharply defined and attention directed to the features that are of significance in the search for ore. Attention should also be given to all characteristics of mineral deposits that might reveal themselves through physical fields or by their chemical environment.

Undoubtedly new ore deposits will be found but it is only safe to anticipate that it will be at a slower rate. Another crop of bonanzas is not to be expected but in the case of some metals such as iron and aluminum, the utilization of lower grade ores could meet all reasonable needs for a long time but at a higher cost in labor, materials and power than is now attained in plants operating on higher grade ores. Leaner ores of copper, lead and zinc will likewise be exploited; but they are in more limited supply than the lower grade ores of iron and aluminum. It must be recognized that dependence on such sources means that the metals will be far more costly, unless marked improvements can be made in the techniques of exploration and mining as well as in concentrating and refining.

Here, indeed, is a challenge to engineers immediately concerned with the field. But it is not the only challenge that the situation makes.

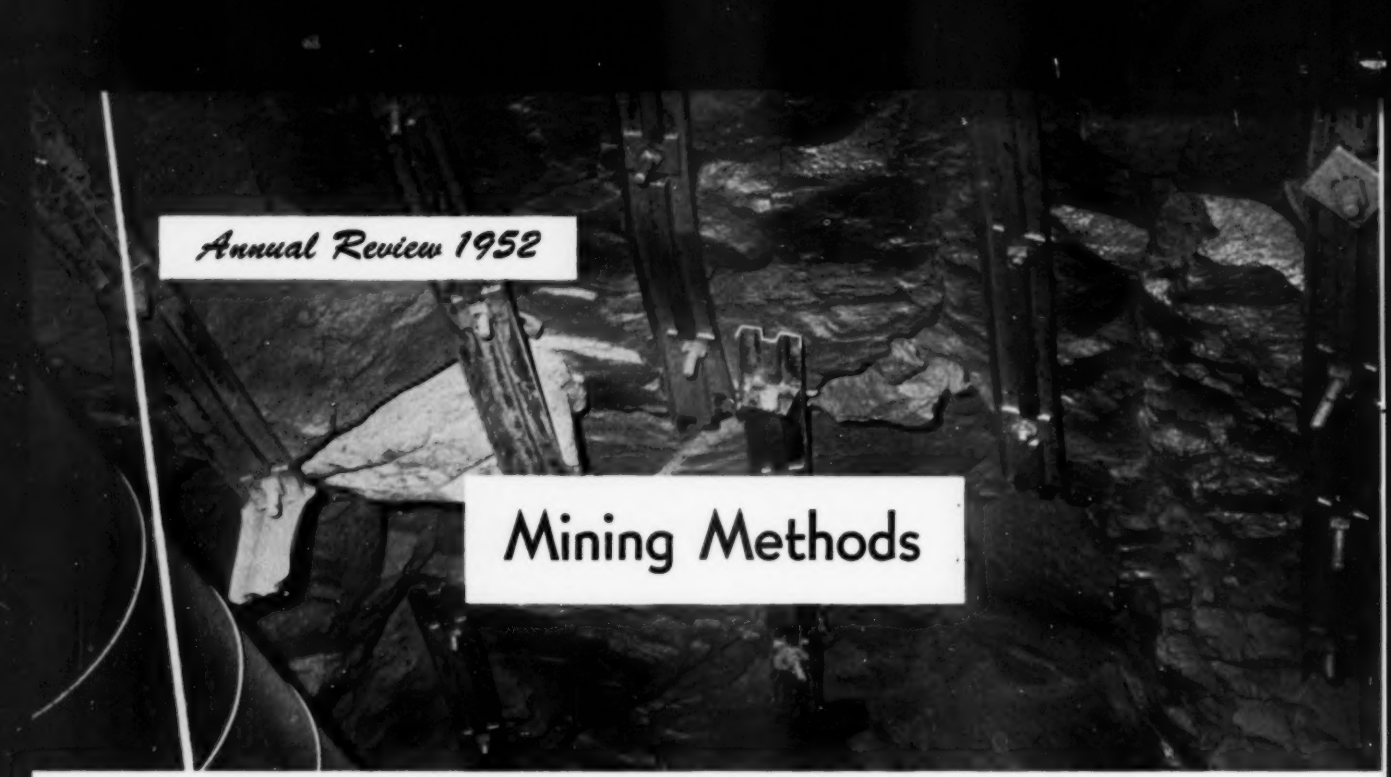
In the century of engineering, the nation has become accustomed to an abundance of natural resources and the products won from them. Under these comfortable conditions, wasteful habits have been acquired. The immense national consumption of metals and minerals rather than the efficient and economical use of these materials has been regarded with pride. Indeed, in these prosperous decades of abundance, the metal producers at most times have been more concerned with finding markets than with overcoming shortages. Consequently, we are rather ill-prepared for the restrictions that are all too likely in the future.

Looking to the Future

In appraising the future, only a blind optimist could fail to recognize the seriousness of the depletion of our mineral resources; but on the other hand no person with reasonable and disciplined imagination is likely to underrate the many ways the situation can be relieved. There is in it, however, a threat to our complacent way of living that is very real—a threat even of disaster if our extravagant habits are allowed to persist and if the problem of declining supplies is not intelligently faced.

The very necessities of the times make it likely that another major surge in the techniques of mining is in the making. Minerals, heretofore of little value, are now in critical demand and developments of utmost significance are dependent on their being available in adequate quantities. Neglected elements such as germanium, lithium, cobalt, and beryllium are all finding unique uses. The exploration engineer, the geologist, the mining engineer, and the metallurgist are being hard pressed to find these new ores, and to master the exacting conditions that their novel properties present. Moreover, even for the common minerals and metals, new sources must be found. The discovery of deposits still concealed will need more subtle and imaginative methods than are now available. The successful exploitation of low grade masses will call for more and more economical and efficient mining or metallurgical methods, and the winning of valuable elements from complex and refractory materials now neglected will need all the scientific and technical ingenuity the age can provide.

With the stimulus and incentive of rewards commensurate with the risk and effort, and under the conditions of free competitive enterprise, no doubt can exist with regard to the outcome. Our engineers and scientists, working with the intelligent cooperation and fellowship that they so well exhibited in the past, can surely be counted upon to respond brilliantly to the new challenge.



Annual Review 1952

Mining Methods

Bolting was substituted for steel sets on Delaware Aqueduct Project; 65,000 ft of tunnel were bolted the first year.

by C. H. Johnson

THE year 1952 has seen the continuance of the trend pointed out by Tell Ertl in this magazine a year ago, toward mechanization in metal and mineral mines. Outstanding progress has been made in the adoption of rock bolting in situations where, a short time ago it would have seemed inapplicable. New devices, better equipment, and improved practices are in part responsible for shifting fashions in mine development, stoping methods, and transportation systems. Only new mines, of course, can take the advantage of the new ideas that are being tested and demonstrated throughout the industry, but the old mines often show a surprising adaptability.

Lower prices of some commodities during the year have only sharpened the constant struggle with costs, and remarks by one of the many committee chairmen and members who furnished the bulk of the material for this review probably would be echoed in many places: "Low prices, combined with thin mines, require constant efforts to improve technique and equipment in order to stay in business . . . Experiments on many small items are always being tried in hopes of saving a fraction of a cent here and there, that might add up to several cents a ton."

Progress in Roof Bolting

Rock bolting has made much progress in the past year. Experimental installations made a year or two ago, as well as tests started in 1953, suggest that bolting has numerous useful applications in metal mining and that considerable savings in timber, improvements in working conditions, and increases in operating efficiency, will be realized. From roof-bolting of open stopes and other wide-backed openings the technique has spread to drifts and crosscuts and to timbered, filled, and shrinkage stopes. In Butte and in the Coeur d'Alenes such uses are being tried experimentally, with many variations in detail of application.

A severe rockburst in the Sunshine mine, at Kellogg, Idaho, in July 1952, knocked down a large amount of rock in a crosscut on the 3,840 level, but within a 100-ft section of the crosscut that had been rock bolted, no rock fell nor were the bolts loosened. Rock bolting of the hanging wall in two stopes at the Sunshine mine in the latter part of 1952 appeared to offer a safe and economical substitute for timber support. The stopes, each 65 ft long, were mined up as shrinkage stopes to a height of 80 ft, then an intermediate level was established and the stopes were drawn empty for inspection. No loose ground was found, and no broken bolts. Now five new stopes are being started, using the same method, wherein every 25 sq ft of hanging wall is supported by five 6-ft bolts, arranged in diamond pattern.

A detail of rock bolting progress that deserves special mention is the use of wood bolts instead of steel. At Day Mines, Inc., Wallace, Idaho, 2-in. Douglas fir bolts are being tried in place of steel bolts in shrinkage stoping and in cut-and-fill (sand fill) stopes to support both hanging and foot walls. The bolts usually are 4 ft long and are set in place by means of long tapered wooden wedges in both ends. Early results have been favorable.

A major step in the development of rock bolting was its adoption in the East Delaware tunnel of the Delaware Aqueduct. After a year of experimentation and the preparation and adoption of plans and specifications, bolting was substituted for steel sets and lagging. At the end of a year, in May, 1952, more than 65,000 ft of 13-ft diam tunnel had been bolted with complete success. Not a single roof-fall accident occurred in this period. A substantial saving of steel was effected, as full support with steel sets required approximately 35,000 lb of steel per 100 ft of tunnel.

C. H. JOHNSON is Chief, Base Metals Branch, Minerals Division, U. S. Bureau of Mines.

Dredging Has Increased

The dredge mining of monazite-bearing placer deposits, which has gone far toward making the United States self-sufficient in monazite, has also brought about certain technical developments in dredging. The monazite placers in Idaho are loose and sandy, with clay streaks, and with flat narrow pebbles rarely as much as 2 to 3 in. in length. Fine screening is necessary, and for this purpose high-carbon, low-manganese steel trommel plates, drilled with holes tapered from 3/16 to 1/4 in. have proved effective, abrasion resistant, and economical. The undersize is treated in a battery of rougher jigs, and the hutch product dewatered and passed through cleaner jigs before being taken ashore for separation of the various heavy-mineral products.

A note of historical interest relates to a British-built bucket-ladder dredge that operated before World War II on the plains of Macedonia, where, according to AIME Transactions, gold was mined as early as 1594 B.C. Now a Greek firm, with the assistance of an American dredge designing and building company, is rebuilding and modernizing the dredge, which was wrecked during the war.

Methods and procedures for the exploration of monazite placers developed in the course of investigations of domestic deposits were described in a recent publication. Chief differences, as compared with gold placer sampling, lie in the handling of the samples. The distribution of monazite is less erratic than that of gold, which permits increased sampling

Baumhoff Marshall No. 1 digging monazite placer near Cascade, Idaho, where dredging has helped toward U. S. monazite self-sufficiency.

intervals, but the recovery, identification, and analysis of the heavy minerals is much more complicated. It is claimed that dredge recoveries have confirmed the exploratory estimates.

Advances in Diamond Drilling

A number of significant advances in diamond drilling equipment and practice have been recorded during the year. R. J. Longyear states that the deepest diamond drill hole in this country (excluding rotary-drilled oil wells using diamond core bits) was completed in 1952 at a depth of 6,010 ft. It was an 80° hole. A separate, high-speed hoist was provided; below a certain depth the standard hydraulic head was rearranged for kelly drive and the feed was regulated by means of a hydraulic tension-control cylinder. The same writer reported increased use of circulating mud in place of clear water, particularly in penetrating overburden, such as glacial drift. Most often, cone or roller bits are used for this purpose, with ordinary drill rigs.

Driller setting hole for diamond drilled ring round at Tennessee Copper Co.

A device for cementing in deep drill holes was described recently by A. E. Ross. A cylindrical injector containing the required quantity of cement is lowered into the hole on the end of a string of rods, just as if it were a core barrel. When it reaches the point to be cemented, pump pressure is applied to the water column in the rods, rupturing a release disk in the bottom of the injector cylinder and forcing the cement out into the drill hole.

Continued investigation of methods of setting diamonds in oriented positions in cast-set bits in order to take advantage of their greater wear resistance in certain crystallographic directions has shown that such setting is feasible and not unduly costly. Considerable number of bits with oriented stones, set by regular employees of commercial shops, are now undergoing comparative tests by contractors.

Three years operation of the Snow Lake gold mine of Howe Sound Exploration Company, Ltd., in Manitoba, made possible a satisfactory comparison of actual results with estimates made prior to underground exploration or development. At this property a 2,000-ton mining and milling plant was designed and built, and mining plans were made and put into effect solely on the basis of diamond drill and surface information. Looking back, after mining and milling 550,000 tons of ore, it is reported that 1—the ground is competent, as foreseen, and no timbering is necessary; 2—the walls of the orebodies are not quite so regular as anticipated; 3—the mine is dry, as expected, with only 50 gal per min to be pumped; 4—the plan of open stoping with long-hole blasting has proved successful (12 tons per man-shift underground); 5—concentration of operations permits the entire tonnage to come from a single level, as foreseen; 6—there has been practically no unnecessary drifting, crosscutting, or raising; 7—mill recovery has been 80 pct, compared with an estimated 80 to 83 pct; 8—the grade has been 8 pct below the estimate before dilution allowance; 9—operating costs are below the 1946 estimate if corrected by 50 pct increase for labor and supplies; 10—capital costs were higher than estimated because of large increases in the cost of labor and supplies in the construction period 1946-1949.

Mining Methods Altered

Block-caving at the Jeffry mine of Canadian Johns-Manville Co., Ltd., at Asbestos, P. Q., is featured by

Jumbos are coming into more and more underground use because of savings in setup time, hole-to-hole time, and elimination of heavy manual work.

concreted draw points and slusher drifts, with the slushers discharging directly into cars on the main haulage level. There are no transfer raises. Blast holes for undercutting the 200x200-ft blocks are drilled with diamond drills. The mine is planned for an ultimate output of 12,000 tons daily.

This is in marked contrast with Braden Copper Company's block-caving operation at Braden, Chile, where transfer raises are long enough to hold a day's supply of ore for the mill (25,000 to 30,000 tons). Caving blocks at Braden are 60x60 m, and 110 m high.

E. P. Pfleider reports from Minneapolis on the status of top-slicing in the iron mines:

"The last few years have seen a partial shift, wherever possible, from the high-cost top-slicing technique to such methods as modified sub-level caving, block caving, and sub-level stoping. Even though the principal stoping blocks are mined by these modified methods, the pillars and irregular portions of the orebodies invariably are still recovered by the very flexible top slicing procedure. Rising labor and timber costs are responsible for this change to methods of higher tonnage output per man and lower timber consumption. Paradoxically, the fee owners originally resisted these changes on the assumption of lower tonnage recovery, only to find that, in practice, tonnage recovery normally runs over 100 pct because of the blending of near-ore in the back. The grade suffers only slightly, and this has not been a problem as yet in a market of high tonnage demand."

The expansion of rock upon fragmentation is the basis for procedures suggested in a recent article to prevent or control subsidence, relieve stress on pillars, and prevent or minimize rockbursts. Briefly, it is proposed that long-hole blasting be employed to fragment considerable volumes of ground above or adjacent to worked-out stopes; that the explosive breaking will be accompanied by volume increase; and that lacking free space into which to expand, the broken material will exert a sufficiently powerful upward thrust to counteract the weight of overburden. This is a much over-simplified statement of the "geofragmental mining method," on which patent application has been made and which is said to be undergoing field tests.

Model testing is a familiar technique in many engineering fields, but in the field of rock mechanics or the design of mine structure has made less progress. An improved centrifugal-testing apparatus for use in mine-structure analysis has been fully occupied until now in connection with rock-bolting studies. Reports on this work are being prepared for publication.

At U. S. Tin Corp.'s mine at Lost River, on the Seward Peninsula, Alaska, long-hole drilling from stations reached by way of footwall raises appears to have solved a dual problem of safety and cost. The ore is soft, blocky and treacherous, but breaks clean from somewhat more competent, regular walls. The vein or "dike" is about 10 ft thick and dips steeply. Timber is locally unavailable, and is brought in only at very high cost. Long-hole drilling, using jointed rock-drill steel, breaks the ground satisfactorily and removes the necessity for men to work in the stopes, thus eliminates the timbering that otherwise would be necessary for safety, and permits shrinkage stoping to be used with little more than the normal footage of stope preparation.

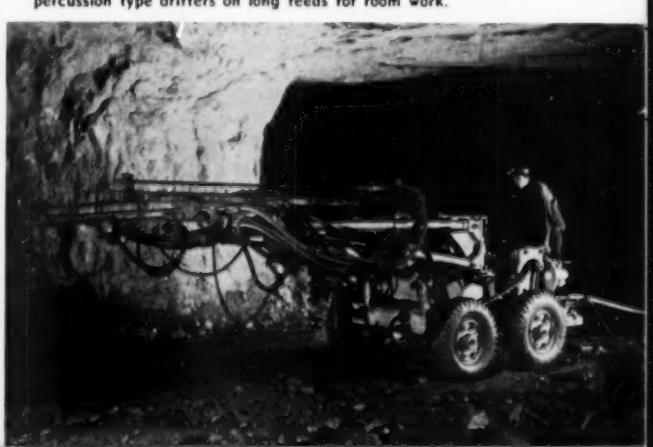
On lower levels of the Morning mine of Federal Mining and Smelting Co., at Mullan, Idaho, where wall conditions are too bad for the conventional horizontal square-set and fill stoping method, blocks 3 sets long and 4 sets high are mined as underhand rills, working from 3-cap raises. The ore is withdrawn from each block and the block is lagged and filled, before proceeding to the next lower block. By this method dilution and repair costs are reduced more than enough to offset the somewhat increased mining cost.

Drilling and Blasting

The status of rock drill, steel and bit development was reviewed in a symposium issue of this magazine in January, 1952.

In underground drilling and blasting there has been continued expansion of the use of pushfeed drills using ⅞-in. collared hexagon hollow drill-steel and with carbide inserts, with carbide insert detachable bits, or with steel bits. This type of drilling was of course originally introduced by the Swedes, however, this year almost every manufacturer in America has come out with a pushfeed drill. In some places where drilling conditions made it impossible to use insert chisel steel bits the use of 4-point cross bits with insert steel was adopted. In some districts there has been a definite trend toward

Self-propelled pneumatic tired "drillmobile" mounting two percussion type drifters on long feeds for room work.



returning to steel bits where the use of carbide has not proved satisfactory.

There has been a very definite expansion of deep hole drilling with sectional rods and couplings and carbide insert detachable bits to replace conventional drilling formerly done with diamond drills.

Conclusions reached by the staff of Homestake Mining Company on rock drills and drill bits, representing the present status of research over the past five years envision "a general purpose drill that the mining industry may use more or less universally as a stoper, sinker, drifter or jackhammer." C. N. Kravig, mine superintendent, after describing briefly the mining methods used and reviewing former drilling practices, described in detail the present drills, steel, bits, and methods used in drifting, raising, and stoping. Light weight drills on pneumatic legs, now standard in stopes, are being tried with success in raises and drifts to replace heavier tools. Detachable tungsten bits are standard throughout. Advantages of the lightweight equipment are summarized:

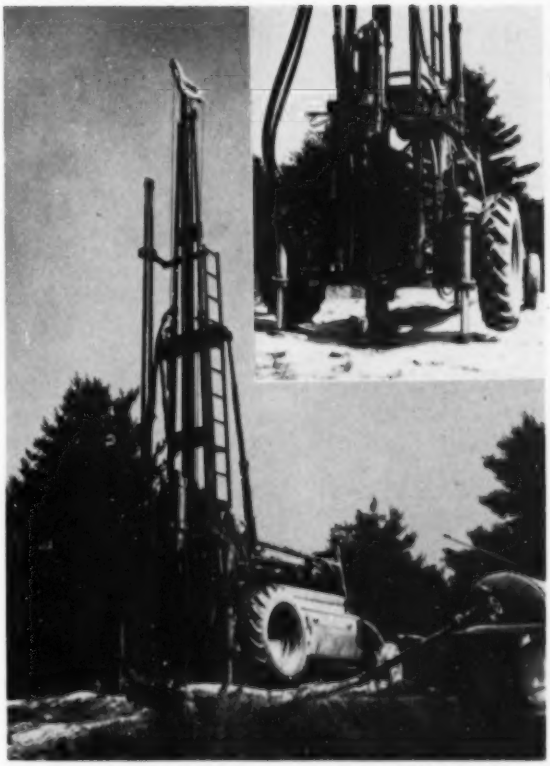
1—Greater drilling speed with tungsten carbide than with steel bits.
2—More drilling time in stopes because of less time for setting up.
3—Greater mobility because of lighter weight.
4—Less physical strain in carrying equipment over pile of broken ore.
5—Lower air consumption per foot of hole.
6—Explosives savings.
7—Less capital investment per stope.
8—A minimum nipping charge.
9—Less cost for racking tungsten carbide bits than one-use steel bits.
10—Any length drill rod may be used.
11—Substantially higher efficiency in tons per man shift.

Mr. Kravig made no comment on the question of alloy steel vs plain carbon steel for drill rods, though, evidently, alloy steel is used.

National Lead Co., in the Tri-State district, for more than a year has used hydraulic-boom drill jumbos with controls at the platform ends of the individual booms. These are said to handle 4-in. machines, mounted on 12-ft feed carriages, with satisfactory stability.

Jackleg-mounted drills also are being used experimentally in the Tri-State, and early reports of increased footage per drill-shift and greatly reduced steel breakage encourage hopes of a successful outcome of the trial. Some difficulty is encountered in ravelly ground.

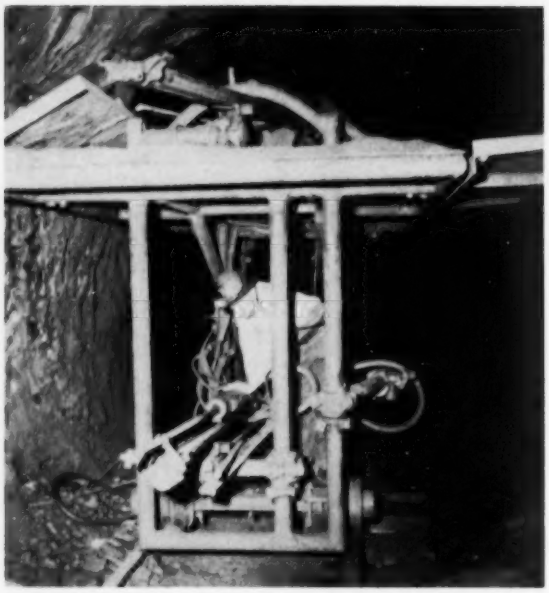
The extension of rotary drills to open-pit blast-hole drilling is an interesting recent development. At two places in Utah the rotary has had almost two years trial, and appears to have advantages over wagon drills. When equipped with tungsten carbide insert bits even a hard quartz formation was drilled rapidly and without excessive bit wear.



Tractor mounted, powerful, percussion type drill has capacity to drill 4½-in. blast hole to depths of 50 ft. Tower can be lowered for moving. Inset detail shows hydraulic leveling jacks.

Starting in June 1951, a mobile drill unit was put under test in the Utah copper pit of Kennecott Copper Corp. as a possible answer to increasingly critical problems of furnishing power, supplies, and service to the standard tripod and wagon drills. The new unit is constructed on a tractor, which provides mobility and furnishes power for manipulating the drill assembly and for driving the two-stage air compressor. A 4-in. drill mounted on a 12-ft carriage can be set for vertical drilling as well as the more

"Drillmobiles" for trackless mining in flat bedded deposits where modified room and pillar methods are used are available with either percussion type drills for hard rock or rotary types for salt, potash, or gypsum deposits. Long feeds permit deep slabbing rounds without steel change.



Two-deck drill jumbo on 42-in. gage track at Tennessee Copper was built and used in driving 11x12-ft haulage drift on 14th level.

usual toe-hole. In 119 operating days the drill averaged 343 ft per 8-hr shift, compared with 112 for the tripod and wagon drills in the same subpit area of the mine. Feet drilled per man-hour was 19 and cost per ft $0.09, compared with 6 and $0.30 for the standard drills.

Millisecond delay electric firing of double-row and multi-row shots, together with shortening of toes and widening of hole spacing has been found advantageous in the open-pit copper mine of Chile Exploration Co., at Chuquicamata, Chile. Timing is controlled by electric motor-driven timers, rather than by millisecond delay detonators.

Pictures of quarry and coal-strip blasts taken with a "machine gun" camera have shown the action of various detonating arrangements. Despite the high rate of detonation of the detonating fuse used in many shots, it becomes evident from the photographs, taken at 1/3 second intervals, that the rock begins to move at the top of the hole appreciably before movement starts at the toe. In such cases bottom-hole priming with millisecond caps may yield better fragmentation, more compact rock pile, with less scatter, and a minimum air blast.

Loading and Transportation

Underground loading and transportation benefitted by equipment advances, moving generally in the direction of larger, more rugged and more powerful units. At Copperhill, Tenn., The Tennessee Copper Co. has completed a centrally located hoisting shaft with a 48x60-in. jaw crusher and 2,500-ton crushed-ore pockets. The 14th-level haulage drift is driven oversize—11 ft high and 12 ft wide—to allow the use of larger cars. A double-deck drill jumbo was built for driving this working. The broken rock was loaded by an Eimco 40 shovel into 11-ton side-dumping cars equipped with large air cylinders to discharge into a bin above the crusher. These cars, as also the solid-body 130-cu ft rotary dump cars used at the Boyd mine of the same company, are featured by eight axel-less, pivoted, spring mounted, roller-bearing wheels. They have ¾-in. steel bottoms and dispense with liners or wood fillers. The track is 42-in. gage, laid on 7x8-in. wood ties.

U. S. Potash Co. is expecting early delivery of a double truck, 8-wheel 40-ton diesel electric mine locomotive. Power will be provided by a 550-hp diesel equipped with double scrubbers. Seven ft wide, 6 ft high and 48 ft long, the machine has been designed and built for complete dismantling so that it can be lowered through the shaft with minimum inconvenience.

A new mine, as already suggested, is the ideal place to apply new ideas, for the entire layout can be designed to make the most of them. The new North Friends Station mine of American Zinc Co. of Tennessee is a case in point. There, 16 men produce 450 tons of ore daily in a completely mechanized underground operation, employing mobile drill jumbos, rocker-type loaders, and Dumptor trucks to transport the ore to surface through an 1,100-ft, 11½° incline. The room-and-pillar stopes are carried 40 ft wide, with full-height headings arranged to permit a maximum use of slabbing rounds. The Diesel power units on loaders and trucks are equipped with exhaust-gas scrubbers, which are regarded as definite necessities in this operation.

Tennessee Coal, Iron and Railroad Co. has further extended its trackless mining method, employing Joy rock loaders, jumbo-mounted drills, and shuttle cars, with a substantial increase in tons per man shift.

Eagle-Picher Co., in the Tri-State, and St. Joseph Lead Co. in Missouri likewise are gaining increasing labor efficiency with this type of equipment.

V. C. Allen, Assistant Manager, Tri-State Zinc, Inc., reported a cost of $0.234 per ton for moving 290,000 tons of zinc-lead ore by truck from the underground faces of the Bautsch mine, near Galena, Ill., to the mill on the surface 1.1 mi away. The haul includes a 2,700-ft 10° inclined adit. Labor accounted for nearly 50 pct this total cost (which does not include equipment depreciation), maintenance somewhat more than a quarter, and tires, fuel and road maintenance the balance.

Recently Eagle Picher has begun production from another mine in the same district opened by a similar truck incline. In this mine, however, the rock passes through an underground crusher before loading into trucks for haul to the mill.

Diesel-electric shuttle car discharging into flight conveyor feeds crusher which is operated by remote control.

Diesel-electric shuttle car has advantages of flexibility, speed, and ability to be used for combination work, loading underground and hauling to surface plant. Compactness and low height features of shuttle car are retained.

It is reported that an equipment need in the Tri-State is for Diesel-powered loaders that can work in 12-ft ground. Manufacturers have promised more rugged machines, with greater accessibility for repairs, in the near future.

Trucking in the Tri-State is facing longer hauls, with a consequent tendency to use larger equipment. Some 18-ton semi-trailers are now in use, and larger ones are contemplated.

One Tri-State mining company is using a Thew-Lorain 25-TL shovel which is said to work in 9 ft 6 in. headroom and to give large output with low maintenance cost. The same operator employs a large semi-trailer truck for underground haulage and reports that it also has high capacity, as well as unusually good maneuverability due to the hydraulic steering feature of the tractor unit.

The importance of truck maintenance cost has been evidenced on the Minnesota iron ranges, where in 1951 some 1,400 trucks moved more than three quarters of the total ore and stripping, by the recent formation of a Range Mechanical Committee which meets monthly to discuss trucking problems and exchange ideas. Minutes are kept of these meetings and findings reported to the participating company management.

Conveyor-belt transportation in underground metal mine holds its own; at Steep Rock underground iron mines and the White Pine copper mine long-section belts are to be used in place of skip hoisting.

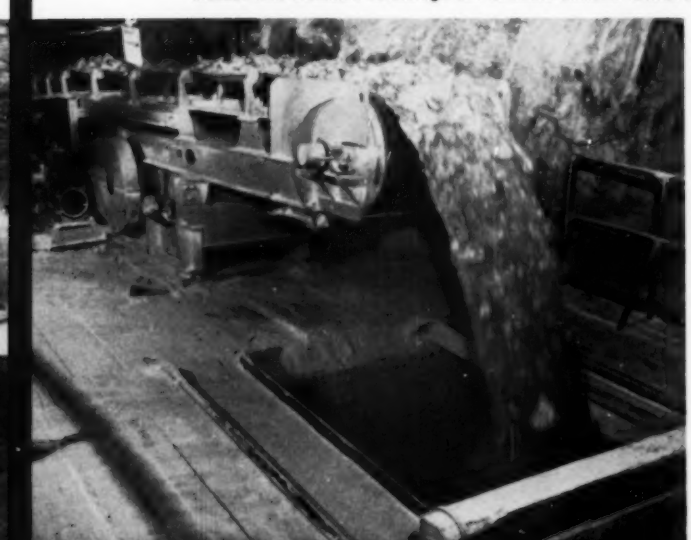
The initial installation of an underground belt conveyor-haulage system in the new Potash mine of the Duval Sulphur & Potash Co., Eddy County, N. M., consists of a 30-in., mine-type conveyor, a single-roll crusher, and an elevating conveyor. The belt is loaded directly from a crusher that breaks the ore down to minus 5 in. The crusher, in turn, is fed by an elevating conveyor that receives the ore from shuttle cars.

The elevator, of the flight conveyor type, has a feed rate of 85 fpm or between 500 and 600 tons per hr. The elevator is operated from a remote control station by an attendant controlling the rate of feed to the crusher and watching for tramp iron and other materials that might injure the belt.

The crusher, of the single-roll type, is mounted on a base that straddles the belt. This base serves as a skid when the crusher is being moved. The crusher has a capacity of over 600 tons per hr.

The belt conveyor, receiving the oré directly from the crusher, discharges into a storage bin at the shaft bottom. Operating at 450 fpm, the conveyor has a peak capacity of approximately 550 tons per hr. The initial installation uses a tail-end take-up, but future belts of greater length will use the internal gravity take-up. The drive section is constructed to be skidded when moving becomes necessary. Intermediate sections of bolted construction are 12-ft long and break down into easily-handled pieces. Carrying and return idlers, 4 in. diam and using pre-lubricated bearings, are spaced 4 ft and 12 ft respectively. Rubber impact idlers are used at the loading point.

Single roll crusher mounted over 30-in. belt conveyor is on skids to permit moving as workings advance. Conveyor receives ore from crusher and transfers to storage bin at shaft bottom. Duval Sulfur & Potash Co.



The belt may be started from either the loading or discharge end, with positive lockouts provided at either end to prevent inadvertent starting. An audible warning signal prior to starting is installed along the belt line. Emergency stop control is provided by a pull cable along the length of the belt.

Hydraulic Hoist

Hydraulic hoisting at the Shullsburg, Wis. zinc-lead mine of Calumet and Hecla, Inc., underwent further testing and development in 1952. Addition of a second pipe column in the shaft converted the system to a U-tube, with some of the water recirculating downward in order to augment the hoisting capacity, which otherwise was limited by the quantity of water available in the mine. Thus the system operates in balance. With 2500 gpm rising in the 10-in. pipe, hoisting capacity is said to be 240 tons of ore per hr. When operating in balance, as a U-tube, the power requirement is reported to be about a third of that for a comparable balanced skip hoist. No long-continued operation has been possible with the experimental installation, but it is believed the early power and capacity estimates have been verified, the automatic control has been shown to be satisfactory, and the dewatering process has been found suitable for this particular situation.

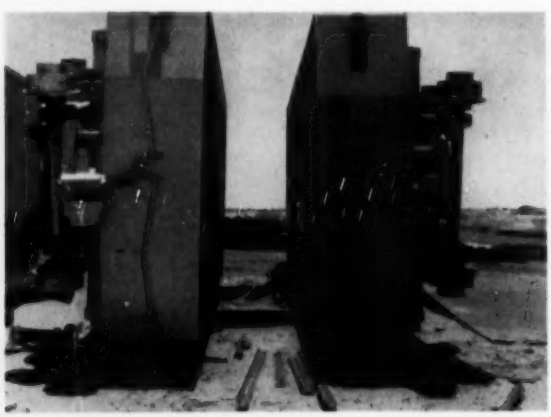
Line-carrier type telephone systems have been installed in a number of metal mines during the year, serving not only for control of haulage but for general underground communications. The units, each consisting of transmitter, receiver, microphone and speaker, take power from a dc trolley line or storage battery locomotive, and are mounted on locomotives or at convenient points, such as shops or underground offices.

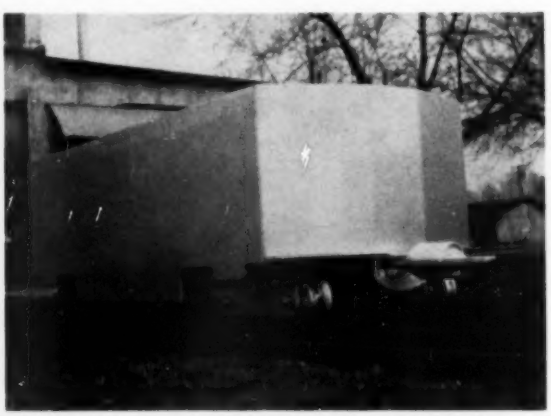
A new man and supply-handling installation at the Boyd mine of Tennessee Copper is a push-button-controlled elevator for sublevel. With haulage levels 400 ft apart ladder climbing has become uneconomical, and it is planned to provide elevator service between each pair of stopes.

The program for expanding sulphur and sulphuric acid production has brought to general notice many interesting engineering problems, particularly those related to the Frasch process in the Gulf Coast area. Not least of the problems has been water supply, for some of the deposits now being brought into production are far from fresh water, and the superheating of salt water in the great quantities that are necessary had not previously appeared feasible. One solution has been to build long pipe lines, or, where reasonably fresh water is unavailable only seasonally, to construct large reservoirs. Freeport Sulphur Co., at its Bay Ste. Elaine mine on the Gulf about 65 miles southwest of New Orleans, installed the first plant that uses salt water, untreated. The water is first de-aerated and at the same time heated to 190°F in packed towers, then further heated in corrosion-resistant heat exchangers to 325°F. Some soft sludge accumulates in the exchangers and must be removed periodically, but conditions are controlled to minimize deposition of scale, although the bay water contains as much as 28,000 ppm salt. Another unusual feature of Freeport's operations is the transport of molten sulphur in insulated barges from Bay Ste. Elaine and from Garden Island Bay, to the storage site at Port Sulphur, on the Mississippi.

An interesting recent development that has furnished a new point of contact between the oil industry and the hardrock miner is the construction of underground storage reservoirs for liquefied petroleum gas (LPG). Large quantities have been pumped back underground in salt domes, but needing storage nearer points of consumption, a number of companies have built or are in process of building underground reservoirs. Problems of exploration, design, access, rock excavation, and sealing off encountered in these projects are more familiar to the miner than to the petroleum engineer.

For the benefit of those who may have to answer the perennial question "What is the deepest mine in the world?" some figures are cited from a recent publication. At the end of 1951 the deepest stoping in the Crown Mines, on the Rand, was at a depth of 8,656 ft below the shaft collar, and the deepest development was at 9,450 ft. At the same time, the deepest point in the Ooregum mine in the Kolar gold field in India was 9,650 ft below the collar. This would seem to award the honor to the latter, were it not for the additional information that "the Crown Mines had reached a depth of 9,681 ft below surface."

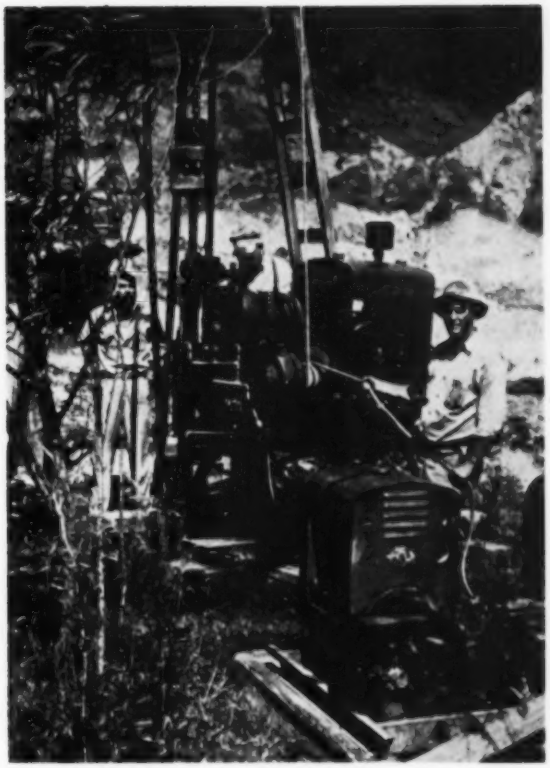




BIGGER AND BETTER mine cars go into use underground. **LEFT**, two 424-cu ft Watt cars readied for trip underground at Southwest Potash Corp., Carlsbad, N. Mex. **RIGHT**, 130-cu ft car built by Differential Car Co. for Tennessee Copper's Boyd mine features thick, ¾-in. steel bottom, without liner. Axleless, with light pivoting wheels, the solid body is designed for rotary dumping.

Mining Geology

by J. D. Forrester



Developments of the year make geologist's industrial position even more secure and important—Professional shortage remains acute—

NINETEEN hundred and fifty-two has been a *year of decision*. Many of the events that transpired will ultimately have as pronounced an influence, it would seem, on the future growth and existence of the United States and of its institutions and individual citizens as did the results of the Boston Tea Party and the outcome of the Civil War. Mining geology as a professional enterprise and also the minerals industry, as a whole, will continue to experience profound effects as consequences of these incidents. Indeed, because of several major happenings during the year, the geologist's industrial position has become even more secure and important than it was at the end of 1951 when Mr. Olaf N. Rove wrote in the February 1952 issue of MINING ENGINEERING that the mining geologist had "arrived" and that the significance of such contributions as the geologist is trained to offer had, at last, become fully recognized.

Regional Exploration Programs

As is generally known, some mining and petroleum companies have applied scientific-engineering geology in its broadest scope for many years. Other organizations, though they have commonly maintained technical staffs and have used geological work with continuing success, recently have seen fit to expand their exploration activities and interests. Many of these new projects are not the *run of the mine* type where the geological work is restricted to rather local areas but they are directed instead to the accomplishment of comprehensive detailed regional studies wherein complete usage is made of advanced geophysical and geochemical techniques and where the pertinency of ore-forming processes and related phenomena is given careful analysis. The writer has been advised of extended geological work now underway, or contemplated, by several companies. For example, Kennecott Copper Corp. during 1952 established five district offices in the United States from which broad geological exploratory surveys are directed. Progressive, long-range planning of a similar nature is underway by Cyprus Mines Corp., Anaconda Copper Mining Co., Phelps Dodge Corp., American Metals Co., St. Joseph Lead Co., National Lead Co., American Smelting and Refining Co., Eagle-Picher Mining and Smelting Co. There are undoubtedly many other important metal and nonmetal mineral producers that have engaged in expanded geological exploration during 1952 and all of such amplified activities confirm that mining geology is on the threshold, at least, of gaining recognition as a necessary and vital professional phase of the mineral industry.

This new development of present and projected mineral exploration work and other events, such as the establishment of the new federal administration, the continuing Korean war effort and re-armament program, the completion and presentation of the Paley Report, the perfecting of new field techniques and the continuing manpower shortage, are of industrial significance. Some of these above elements unqualifiedly are fortunate, others in contrast are less encouraging but each has a bearing on the welfare of the nation's mineral industry.

Professional Shortage

College enrollments and the attendant current supply of graduates in geological science and engineering remain at a low level and it was defined at the Manpower Conference held in September in Chicago that the situation, so far as available pro-

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fessional men is concerned, steadily has been growing worse. This present shortage, projected into the future, becomes even more critical when it is recognized that the existence of scientists is an acute element of our industrial growth. The number of competent specialists available to aid in furnishing mineral commodities must be ever greater in order to continue to accomplish the sustained progress the United States must experience if it is to compete successfully with other countries. That is, even though the present supply of men is less than needed, the expanded professional enterprise that will be necessary to find new mineral deposits for maintenance of the American economy will well require more and more scientists and engineers. The problem of technical manpower is extremely serious and its solution will demand aid from all possible sources. Statistical studies recently concluded by Mr. B. H. Wilson and reproduced in the A.G.I. *News Letter*, Vol. IV, No. 3, November, 1952, demonstrate that high school students, from which future geologists must come, are not being given an opportunity to appreciate earth sciences. Whereas in 1900, about 30 per cent, or 154,000 individuals, of the nation's high school students were able to become acquainted with earth sciences through curricula offered by secondary schools, only 0.4 per cent (20,575) of the total high school students had the opportunity in 1950 to study such material. The numbers have progressively decreased and the present relationships probably are even more serious.

Major effects of the manpower situation in the United States will continue to prevail unless means are found to curb and remedy the condition that potential professional geologists, geophysicists, and mining engineers are being lost through lack of educational contact. The economic status of the nation is threatened because technical men are not being made available to discover and develop future supplies of mineral materials.

As foretold by many mineral economists before the beginning of the year, the pace of overall commodity production has continued to increase during 1952. The minerals industry reflects the re-armament program presently in vogue and it apparently has become essentially adjusted to the "Korean economy".

Expanded Future Demands

The President's Materials Policy Commission (PMPC) has presented an analysis of its findings on future raw materials requirements and natural resources of the United States. The study was undertaken particularly to estimate conditions that will prevail during the decade of 1970-1980 and the report, issued in five volumes and commonly designated as the "Paley Report" has been received with much interest. The primary purpose was a study of the long-range needs of the United States so that intelligent planning could be accomplished to keep raw materials available to industry but, at the same time, to avoid the world-wide dislocations that could be caused by uncontrolled production. As stated in the report, "The overall objective of a national materials policy for the United States should be to insure an adequate and dependable flow of materials at the lowest cost consistent with national security and with the welfare of friendly nations".

The report has many facets of direct significance to mining geology. Regardless of our agreement or disagreement with the findings and recommendations presented by the PMPC, the fact remains that our future mineral needs will transcend present production by great quantities. That is, even though we may not agree fully with the Commission's proposals concerning taxation, revision of Federal mining statutes or tariffs, etc., we are obliged to recognize that the demands of an expanded mineral economy must be met.

This need will probably extend the activities of the U. S. Geological Survey and the Bureau of Mines. In addition, geological work by private enterprises and by various state agencies will play a vital role in meeting the challenge of the requirement for new and varied mineral commodities.

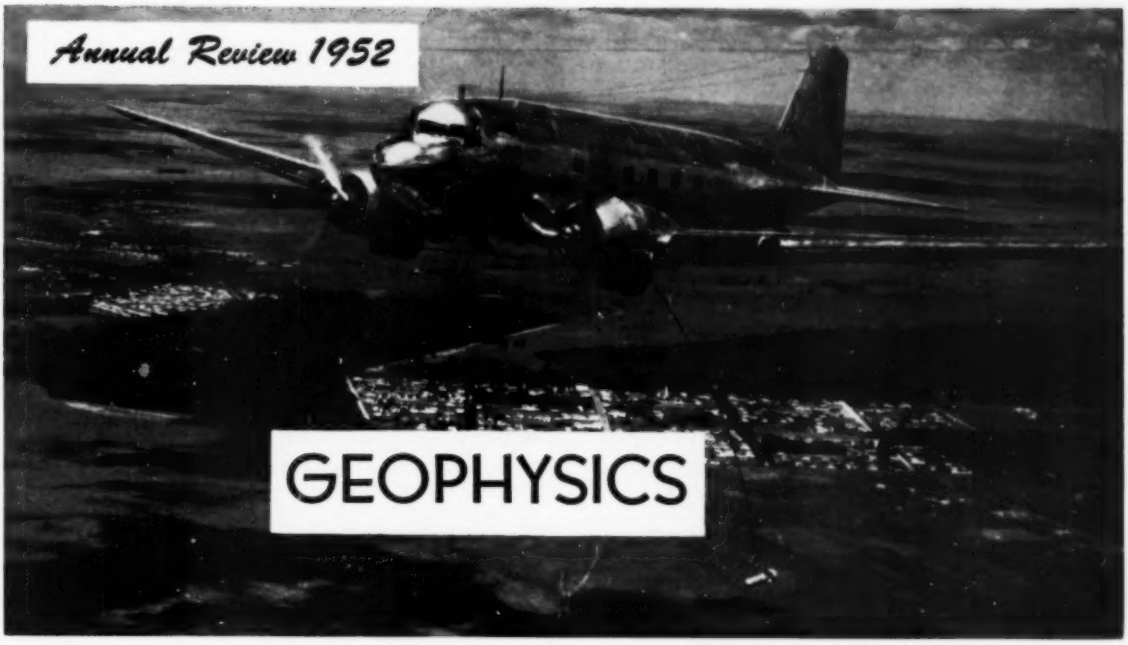
The Influence of Government

The election in 1952 of a new Federal administration having a different philosophy of state-craft than that which has prevailed in the United States for over two decades undoubtedly will have an impact on mining and petroleum geology. The political campaign conducted by President Eisenhower, and unquestionably reflecting his tenet of government, was characterized by continual reference to "freedom of the individual", "less government control", and "states rights". The probable decline of federal bureaucracy, particularly in economic and social areas where such agencies do more harm than good and the new point of view as regards ownership of tideland oil and other resources will be reflected, in the writer's opinion, by spurred industrial activity and expanded exploration. The overall mineral industry situation has been, and will continue to be, influenced also by the Supreme Court ruling on seizure of the steel companies and by the recent virtual collapse of the Wage Stabilization Board which was induced largely by the presidential ruling on coal wages as handed down on December 1952.

The refinement of exploration techniques and the discovery and development during the year of new metallic and nonmetallic mineral deposits has been noteworthy. The airplane is being used more ever-extensively in prospecting work and geochemistry and geophysics have been applied successfully in the search for otherwise hidden ore bodies. Research studies of metallic and nonmetallic occurrences by the U. S. Geological Survey and the Bureau of Mines have been intensified. As illustrations of the type of broad work being done, it is reported that the Geological Survey has discovered potentially significant deposits of uranium in the Powder River region of Wyoming and that it has published the first three of nine preliminary reports containing data on public water supplies of more than 1200 cities in the country. The Bureau of Mines, among other activities, publishes a monthly inventory called *Mineral Trade Notes* which is a compilation of information obtained from U. S. foreign service offices and other sources. The statistics are offered in two classes, namely: I. Metals; II. Industrial Minerals. Also, detailed surveys are being made of various mineral materials and the summations that result are published as "Commodity Reports".

Many state agencies likewise have been active in analyzing the mineral potentials and occurrences of their respective regions.

It is apparent from the foregoing, as a whole, that 1952 has been indeed an exceptional year of importance to the advancement of the minerals industry and, hence to the profession of mining geology.



Aero Service Corp. plane flying magnetometer survey over gold mine area in South Africa.

Geophysical search for minerals is stepped up to meet requirements of expanded defense program—Seismic and electrical surveys become firmly established for ground-water and engineering investigations.

by H. R. Joesting

INCREASED demand for minerals and fuels has resulted in stepped up geophysical activity in all parts of the world. The use of geophysical methods has long been routine in the petroleum industry; now mining companies are more and more looking to geophysics to help replace depleted ore reserves. The airborne magnetometer, developed during World War II, has won an important place in the exploration programs. The race for atomic supremacy has led to increasing use of the airborne scintillometer in the search for uranium deposits as well as to use of vehicle and hand-carried counters.

In this review an attempt is made to point up the more outstanding events, advances, and discoveries and trends in geophysics, with emphasis on mining and engineering geophysics.

About 75 correspondents in all parts of the world, representing oil and mining companies, geophysical contracting companies, universities, and government agencies, submitted information on geophysical surveys of special interest, including discoveries of minerals; on advances in instruments and methods; on pertinent results of research in earth physics; and on trends indicated by events in 1952.

Considerable information was received on geophysical activities in the United States, Canada, and Europe. Information was spotty from Africa, the Middle East and Asia. Very little information was obtained from Latin America and none at all from the Soviet Union and her satellites.

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United States

In the United States geophysical activity in the search for minerals and fuels has been stepped up to meet the requirements of an expanded defense program, increased consumer demand, and constantly taxed reserves. Seismic and gravity surveys for oil were up 15 pct during the first nine months of 1952; mining companies are increasingly relying on their own geophysical programs; seismic refraction and electrical resistivity surveys have become firmly established in ground-water and engineering investigations.

United Geophysical Co. reports the discovery of a copper deposit in southwest Arizona which is now undergoing development; and Newmont Exploration Co. reports discovery of a sulphide deposit of possible economic importance.

National Lead Co. conducted electrical resistivity and magnetic surveys during 1952 in investigations of the lead deposits of the Fredericktown, Mo., district. The M. A. Hanna Co. is currently engaged in magnetic work in the Lake Superior District and the Jones & Laughlin Steel Corp. reports that it uses gravity, magnetic, and electrical methods in the search for iron ore.

Although electrical and magnetic methods have won a firm place in the exploration programs of

several major mining companies, gravity surveys are gaining wider usage. Gravity work in the Iron River-Crystal Falls area of Michigan has been conducted by Radar Exploration Co. for the Cleveland-Cliffs and M. A. Hanna Companies. Michigan College of Mining and Technology has recently done gravity work in this area which, during 1952, was extended to include the western third of the Upper Peninsula. Excellent correlation between Bouguer anomalies and regional geologic features was reported. A gravity and magnetic survey of an area near Bear Lake, Houghton County, Michigan, appears to indicate differentiation of magnetite within the felsite intrusion.

William M. Barret, Inc., reports Radore exploration for new lead deposits in southeastern Missouri, the Ducktown District of Tennessee, and the Globe District of Arizona. Barret reports that the discovery of the Indian Creek ore body in Missouri in 1951 followed Radore exploration.

To supplement geological studies of rock alteration as a guide to ore deposition in the East Tintic Mining District of Utah, geochemical, geothermal, and geophysical tests were made by the U. S. Geological Survey. Self-potential and resistivity measurements were made, both at the surface and in test holes. Brief tests in the Grants, N. Mex., district were made by the Survey to correlate airborne and ground magnetometer data. Preliminary magnetic and electrical-resistivity work was conducted by the Survey in the Shasta Copper Mining District of California. In the Colorado-Utah Plateau, the Survey has conducted extensive geophysical surveys in connection with its program of uranium exploration on behalf of the AEC. The U. S. Bureau of Reclamation reports that it conducted experimental resistivity and seismic surveys in the same region with encouraging results. Regional gravity work was done by the Survey in the Sierra Nevada of California and in the Steamboat Springs area of Nevada, the latter to check the relationship between magnetometer anomalies and gravity features.

A total of 30,000 miles of airborne magnetometer traverse was flown by the Survey in Arizona, Colorado, Maine, Minnesota, and Wyoming. The work in Arizona, Colorado, and Wyoming was part of the uranium exploration program for the AEC; here airborne scintillometer measurements were also made. The Minnesota survey was flown over the western extension of the Lake Superior Iron region, and the Maine survey for geologic information.

Airborne-magnetometer maps of the Katahdin area, Maine, compiled by the Survey, were used by Sherwin F. Kelly to select areas for investigations by spontaneous polarization in the search for massive pyrrhotite deposits similar to that near Mt. Katahdin. Some additional detailed airborne-magnetic work was also done in selected areas by the Aero Service Corp. These investigations were made for the Freeport Sulphur Co. Electrical-resistivity tests were conducted by Kelly, in cooperation with Leggette and Brashears, to delineate a prominent fault system on the east side of the Hudson River in New York. The fault system serves as a water-bearing aquifer. Kelly continued investigations of sulphide deposits in Virginia and nearby States by spontaneous polarization methods.

The use of radioactivity methods expanded somewhat during 1952, largely as applied to uranium prospecting. Several thousand portable radiation detectors, mostly the well-known Geiger counter, are now in use. Considerable and reasonably successful prospecting has been accomplished with specialized radiation-detection equipment mounted in cars and aircraft. Gamma-ray logging of exploratory boreholes to locate and evaluate radioactive materials has been used effectively, largely by government agencies, with a total footage studied approaching 1 million ft per year. The current demand for uranium, coupled with foreseeable advances in instrumentation and methods, indicates continued expansion of radioactivity methods of exploration.

Geophysics (principally seismic refraction and electrical resistivity) can now be regarded as firmly established in ground-water investigations and certain engineering problems, such as location of sand, gravel, and other construction materials, and in bedrock-depth determination in conjunction with highway, dam-site, and other construction activities. Only in the petroleum industry have geophysical surveys gained such wide acceptance. Geophysics is widely used for these purposes by the U. S. Geological Survey, the Bureau of Reclamation, the Bureau of Public Roads, and several State geological surveys and municipal governments, as well as private companies.

Canada

Canadian mining companies have long made use of geophysical methods in the search for mineral deposits, and the last few years have seen an increase in the use of seismic-reflection and gravity methods in oil exploration following recent major discoveries.

Toronto was the site of the Eastern Regional Meeting of the Society of Exploration Geophysicists in October 1952. At this meeting at least half of the papers related directly to mining geophysics and several others had significance to the mining industry. This increased attention to mining problems by professional geophysicists contrasts with most past SEG meetings, in which petroleum geophysics predominated, and should stimulate progress.

Aeromagnetic Surveys Ltd. in 1952 conducted an airborne-magnetometer and scintillometer survey of 575 sq miles in the Sudbury District for the Ontario Department of Mines. In northeast Alberta the Geological Survey of Canada completed an airborne-magnetometer survey over the tar-sands area; they report that it is impracticable to do airborne magnetic work north of 60° latitude because of the frequency and violence of magnetic storms. An airborne-magnetometer survey is reported to have been made for National Lead Co. over 1500 sq miles in the Mealy Mountains of Laborador in the search for titanium; ground magnetic work has also been done here. Ground magnetic exploration for titanium was also done at Roberval, Quebec Province. The airborne magnetometer was used for the first time in British Columbia, investigating magnetite deposits on Vancouver Island, according to information received from the Victoria Department of Mines.

The Canada Department of Mines and Technical Surveys compiled regional gravity maps of Alberta, Saskatchewan, Manitoba, and the Maritimes.

In Canada, S. H. Ward has used variable-frequency electromagnetic equipment in the Sudbury area at the Mount Nickel ore body and at the Radenhurst-Caldwell magnetite deposit in the Grenville sub-province of Ontario.

Geophysical Explorations Ltd. conducted resistivity and spontaneous polarization surveys on ice-

Scintillometers become carborne as well as airborne. LEFT—Jeep-mounted counter used by South Australian Dept. of Mines. CENTER—Carborne scintillometer developed by Oak Ridge National Laboratory and U.S.G.S. RIGHT—Installation of graphic recorder for scintillometer.

covered lakes for sulphides in the Temagami area in the vicinity of Sioux Lookout. Gravel beds suitable for exploitation were the objective of a resistivity study in Ontario; and copper-nickel deposits in the Sudbury area were investigated by use of spontaneous-polarization and magnetic observations.

The Newmont Exploration Co. performed research on a large pyrite deposit on the north coast of British Columbia and on a nickel deposit on the lower Fraser River.

Hudson Bay Mining and Smelting Co. and the Canadian Nickel Co. have been active in Manitoba in the search for ore deposits, using magnetic and electrical methods.

Latin America and Caribbean

Information on geophysical activities in South America is sparse but it is known that there is considerable activity in the search for oil and apparently for other mineral deposits.

In Brazil the government-controlled Cruzeiro do Sul Airline with the cooperation of Aero Service Corp. has initiated a long-range program of airborne magnetic and radiation surveys. The Geologic Institute of Peru reports that most geophysical surveys in Peru for deposits of economic interest are conducted by contracting companies for U. S. private interests. The Aero Service Corp. in 1952 made a survey of 600 sq km in northern Peru over the Marcona Iron deposits for Utah Construction Co.

The Hoard Exploration Co. made a gravity survey of 2000 sq km in northern Peru for the Empresa Petrola Fiscal, a Peruvian government agency, to study basement configuration. Electrical and gamma-ray logging in drill holes was also conducted here for the Peruvian concern by Schlumberger and Halliburton. The Peruvian Geologic Institute uses resistivity and magnetic methods for ground-water studies.

Trinidad Leaseholds Ltd. reports two seismic-reflection parties are working in southern Trinidad and the Gulf of Paria. Some magnetic work is being done in Cuba and the Geological Survey of Jamaica is engaged in Geiger-counter and dip-needle work. Sherwin F. Kelly reports that his company conducted spontaneous-polarization surveys in Cuba in Holguin Province and in the Province of Pinar del Rio. Resistivity measurements were used to check the spontaneous-polarization results. Gravity and seismic surveys were conducted in the Bahamas by the Bahamas Exploration Corporation Ltd.

Paul C. Wuenschel has completed a regional gravity study of South America, encompassing the area from 15 to 33 degrees south latitude.

Europe

Sweden appears to be one of the most active countries of Europe in mining geophysical prospecting, both by the government and by private companies. Airborne surveys by Lundberg Explorations Ltd. located many magnetite ore bodies. Ground magnetic and electromagnetic methods, the latter employing loops in the form of squares two miles on a side, were used successfully by Bolidens and the Swedish Geological Survey in combination with gravity methods to locate deep-seated sulphide ore bodies in the Skellefte area. Other geophysical work included further *loop-frame* and magnetic surveys at Kirima for copper ore, and resistivity surveys in the Caledonian Mountains.

In Iceland the principal geophysical work of the State Electrical Authority centered around development of the hot-water fields as Sandarkrokur in northern Iceland, Reykjanes in southern Iceland, and others of less importance. Electrical-resistivity surveys were supplemented by gravity and magnetic measurements. Similar surveys were made at Namafjall to locate sulphur-rich volcanic gases.

Seismic-refraction measurements in a coal mine in England by Mining and Geophysical Services Ltd. determined thickness of overburden with a maximum error of 7 pct in 40 to 150 ft. In Cornwall radiation methods are being used by the British Geological Survey for mineral exploration.

Reports of work on the Continent show that geophysical prospecting is used extensively in Italy, both by the government and by numerous foreign contracting companies. The entire Po Valley has been explored and the search continued for new oil-producing areas. Seismic-reflection surveys have resulted in the discovery of several promising structures in the Po Valley as well as a gas-producing structure in central Italy. In Sardinia as well as in Italy electrical, magnetic, and seismic investigations were made for ferrous and non-ferrous deposits.

In France the Compagnie Générale de Géophysique has nearly completed the gravimetric reconnaissance of the Paris basin, and has made reflection seismic, telluric, and resistivity depth measurements for oil in southern France. They have also discovered a pyrite ore body in central France by spontaneous-polarization methods, and made seismic studies of the site of a proposed hydroelectric development at the Bay of Mont Saint Michel.

Radiation methods of prospecting are being used by the Commisariat a l'Energie Atomique.

The Instituto Geologico y Minero of Spain has made resistivity and seismic measurements for ground water, in some cases at considerable depths, and also used seismic-refraction methods for coal investigations in Cordoba Province. The Yugoslavian Geological Survey is also using electrical methods successfully to locate water in karst areas of Serbia.

Africa and the Middle East

In Africa there has been considerable routine resistivity work in ground-water investigations by the government agencies, but the major part of the geophysical exploration for minerals and oil has been conducted by private companies. The Compagnie Générale de Géophysique has made extensive seismic surveys of complex deep structures in northern Algeria and Morocco, and electrical depth profiles in Tunisia. This company is also engaged in a large-scale gravimetric reconnaissance of the Sahara, with some use of seismic and telluric methods. A similar program is under way in the dense jungles of Equatorial Africa where an electrical spread up to 30 km was used. A regional electrical and telluric survey is near completion on Madagascar, with detailed checking by electrical and seismic methods. Results of electrical surveys for water in French West Africa and at several American airfield sites in French Morocco were verified by drilling. In Algeria the same company made electrical surveys which resulted in the discovery of lead and zinc ores along one of several major faults.

The Geological Survey in Sierra Leone is making ground magnetic studies to determine the base of the norite-gabbro complex and associated titanomagnetite under sediments of Pleistocene age on the Colony peninsula. In the Belgian Congo seismic, magnetic, and gravity surveys have been made by the Societé de Recherches Minieres en Afrique to determine thicknesses of Karroo and post-Karroo sediments in the central basin of the Congo River. Self-potential, magnetic, and resistivity methods have been used by the Mines and Geological Department of Kenya to locate manganese laterite in Mrima, southeastern Kenya. Aeromagnetic surveys followed by detailed ground magnetic, resistivity, and self-potential measurements have been made in northwestern Swaziland according to the Geological Survey of Swaziland, but no results have been released. The Geological Survey Department of Tanganyika has made magnetic surveys for segregations of magnetic sands in alluvium.

In addition to resistivity and self-potential surveys for the location of water wells, the Uganda Geological Survey has made a gravimetric survey in the valleys of the Sukulu hills in eastern Uganda to locate residual soils containing apatite and other minerals of economic value. Induction equipment from Sweden was used in further exploration of the sulphide ore bodies on Mt. Ruwenzori, and a magnetic survey was made over the magnetite deposits in eastern Uganda. The Geological Survey of Southern Rhodesia has been able to detect the various rock types of the southern part of the Great Dyke by magnetic traverses. Geophysical Surveys Ltd. of Rhodesia, has specialized in water surveys principally by the resistivity method, making nearly 700 surveys. This company also is making a magnetic survey in the Wankie coalfield to locate irregularities in the Pre-Cambrian which have interrupted the deposition of the coal.

Some geophysical activity has been noted in the Near East. The Mining Research and Exploration Institute of Turkey has completed a successful magnetic survey for chromite, and used resistivity, electromagnetic, and magnetic methods to locate water-bearing cavernous limestone in central Anatolia. The same organization has made a regional gravity survey in the Adana Basin for structures favorable for oil. Second vertical derivatives are being used to distinguish shallow structures from deeper ones. In Cyprus resistivity, self-potential, and gravity methods have been used by several companies in searching for pyritic ore bodies.

Asia, Australia, and the Pacific Islands

The Geological Survey of India conducted self-potential and resistivity surveys in the search for sulphides as a source of sulphur in four areas: Kunibarmesedikese, Mysore State; Gani, Madras State; Polur, Madras State; and Kaiga, Bombay State. Several strong self-potential anomalies were mapped and, in the Polur area, exploratory drilling has been recommended on three prominent anomalies. Electrical and magnetic exploration for copper ores was carried out in the Singhbhum area, Bihar State, and in the Sleemanabad area, Madhya Pradesh State.

South Australia has an active geophysical program in which the State and Commonwealth have participated. Among the projects completed in 1952 were gravity surveys of 5000-sq miles in the lower southeast portion of the State and of 1000-sq miles at the Moorlands brown-coal field; a 2000-sq mile airborne radioactivity survey of the exposed Archean rocks north and west of Radium Hill, which resulted in the discovery of radioactive minerals at Crocker's well; airborne magnetic surveys of an area surrounding the iron ore deposits of the Middleback Range and another area on the Yorke Peninsula; and a 100-sq mile radiation survey between Kadina and Moonta on the Yorke Peninsula, using a jeep-mounted scintillometer. Local surveys included gravity and ground magnetic measurements for iron ore near Camel Hill Range, and various airborne measurements of radiation anomalies.

In New Zealand, geophysical work is carried out by the Geophysical Division of the Department of Industrial and Scientific Research. Detailed investigations have been made in the Wairakei thermal area, where drilling for steam for a 20,000-kw station is now under way. Geophysical work includes seismic, magnetic, electrical, and gravity surveys, and temperature, heat flow, and discharge measurements of wells and springs. Similar but less detailed work has been done in the Te Teko area. An aeromagnetic survey covering 17,500 sq miles has been made of the volcanic region, and a regional gravity survey is now under way.

Research and Development

Considerable interest has been indicated in magnetic, density, and acoustic logging of oil wells. It would seem that such logging systems would be of equal interest in mineral prospecting. Newmont Mining Co. is investigating the theory and use of electric logging for conducting ore bodies, as well as of other electrical methods of prospecting. The

Microlaterolog has recently been announced by Schlumberger as a further development of the Laterolog method of oil-well logging; and a Microlog Continuous Dipmeter has also been developed.

The United Geophysical Co. reports that it has carried out 18 crew-months of research in mining geophysics during 1952. Several mining companies are also reported to be conducting aggressive research programs.

Changes and improvements in scintillometers and similar radiation equipment are limited mainly by the availability of crystals and special electronic components. The U. S. Geological Survey and Oak Ridge National Laboratory have jointly developed a new scintillometer weighing about 6 lb, which is now available to the public from three firms for about $500. Portable gamma-ray logging equipment for small-diameter holes has also been developed by the Survey and the AEC as well as by the National Research Council of Canada. Carborne scintillometers are now in use.

Shallow reflection seismic equipment using high-speed cameras and special filtering has been developed by Stanford Research Institute and by at least one other ogranization. The Magnolia Petroleum Co., in cooperation with the Ampex Electrical Co., has developed a system of recording seismic signals on magnetic tape, in which 12 channels are recorded on tape 1 in. wide. The signal is recorded on a wide-frequency band (5 to 200 cycles) and analyzed on a cathode screen with a wide choice of filtering, mix, and gain. When the best record is obtained on the screen a conventional record is taken on a camera-type oscillograph. Magnolia has also made studies of electromagnetic-wave reflections from resistivity interfaces.

The British Directorate of Colonial Geological Surveys has set up a series of seismic stations in the West Indies to study the possibility of predicting eruptions and harnessing steam for power. The U. S. Geological Survey is also conducting volcano research in Hawaii and the Aleutian Islands. The Canadian Geological Survey reports that a line of pendulum and gravimeter stations has been established between Mexico City and Winnipeg to aid in gravimeter calibration.

Gravity, seismic, and magnetic measurements have been made in many parts of the Atlantic and Pacific Oceans by the Lamont Geophysical Laboratory of Columbia University; and extensive trans-Pacific seismic surveys have likewise been made by Scripps Oceanographic Institution.

The availability of aeromagnetic data over large areas has encouraged compilation of continent-wide magnetic-anomaly maps by several organizations; and these may be expected to yield fundamental information on continental structure which will eventually be useful in guiding the search for minerals.

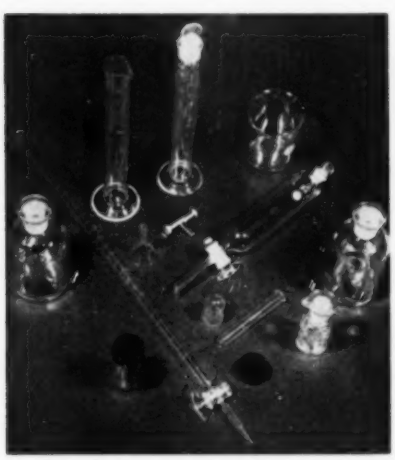
Trends

In petroleum geophysics the trend continued toward refinement of instruments and methods and toward more detailed and quantitative interpretation. At the same time, the industry is becoming increasingly concerned with all phases of earth physics that bear on the origin, migration, and accumulation of hydrocarbons.

In the mining industry there is an increasing realization of the need to establish geophysical prospecting on a firm experimental and theoretical basis. This has led to an encouraging amount of research, not only in instruments and methods but in the relating geophysical measurements to rock properties and to geologic factors affecting the occurrence of ore.

Engineering and ground-water geophysics will doubtless continue to be increasingly used as its value becomes more widely known. Continued refinement and miniaturization of equipment will accelerate this trend, as long as construction and industrial activity remains high.

The compiler of this review thanks each who supplied information. Thanks are also due to Louis Pakiser and Elizabeth King of the U. S. Geological Survey who abstracted and compiled a large part of the information that is presented here.



Intense interest has developed in geochemical and geobotanical methods. Samples are easily taken, and glassware, left, for trace metal analysis is another aid to the geologist.

Big New Plants Highlight Beneficiation Development

by E. H. Crabtree

Research on the iron ranges begins to bear fruit in big plant construction — Big coppers raise capacity, build at new Arizona, Michigan, Nevada, properties — Hydrometallurgy comes to fore with new uranium ore treatment and the Chemico process for nonferrous metals —

IF the predictions of the Paley Commission for metal requirements in 1975 are anywhere near correct, then the developments in 1952 were a long step in the right direction. The year either saw the start of construction or the start of actual operation of many new large milling plants. Several "world's largest" pieces of milling machinery were manufactured, and new processes or new applications of old processes were being tried out in almost all branches of the industry.

New Concentrators

Leading the field were the irons and the coppers. The tremendous amount of research on the iron ranges, indicated in previous annual reviews, was starting to bear fruit. The pilot plant of the Reserve Mining Co., at Babbitt, Minn., designed to produce 300,000 tons of taconite concentrates annually, was put into operation. This plant will be followed by the large plant near Beaver Bay with an ultimate projected annual production of 10 million tons, and will treat 83,000 tons of crude ore per day. Construction of the first units of this plant was started.

The Erie taconite plant at Aurora continued operation and completed a second pelletizing furnace for agglomeration of magnetic taconite concentrates. Cyclones were substituted for spiral classifiers in the grinding circuit with reported good results. With a current capacity of 200,000 tons of concentrate per year, plans are to ultimately expand this to 10.5 million tons. Handling 88,000 tons of feed per day, this will then be the world's largest concentrator.

The pilot plant of Oliver Iron Mining at Virginia, Minn., with a capacity of 500,000 tons of iron concentrate per year was scheduled to start in late 1952. The Western Mining Co.'s West Hill mill near Colerain, Minn. will treat 700 long tons per hr by screening, washing and heavy media.

Construction of the Cleveland-Cliffs' Humboldt mill at Negaunee was started. With an initial capacity of 200,000 tons of iron concentrate per year, this will be the first to use flotation, and the first commercial iron ore beneficiation plant in Michigan.

A heavy-media plant of the Woodward Iron Company at Birmingham will treat 400 tons per hr. Scheduled to start in the spring of 1953, it will separate slate and sandstone from iron ore at 3x¼ in. size by heavy media to produce a concentrate containing about 35 pct iron.

In the field of the new coppers, Anaconda's Chile Exploration Co. started its $110 million Chuquicamata concentrator for the treatment of sulphide copper ore from the famous Chuqui orebody at the rate of 30,000 tons of ore per day. The plant, comprising a concentrator, smelter, and waste-heat power plant has been laid out for simplicity in materials handling; all track being parallel, and conveyors at right angles to each other. Over 100 pct expansion has been allowed for and this to be made without interference to operations. Piping and electric power lines were laid in carefully constructed tunnels for maintenance, accessibility, and least obstruction.

Construction of a new crushing plant for the sulphide concentrator is under way but temporarily ore is being crushed at the existing oxide-plant crusher. The oxide plant is continuing to treat oxide and mixed ores but at a rate reduced from the previous capacity of 60,000 tons per day.

The concentrator is divided into 10 sections each containing two-stage rod and ball mill grinding, rougher flotation, regrind ball mill and classifier, and final flotation section. Thickened and filtered concentrate goes to bedding plant from which it is

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smelted in reverberatory furnace and converter before casting into blister cakes. Production will be 450 tons per day of copper from sulphide plant.

Simultaneously, the new plant of the Greater Butte Project was getting under way. The new leach-precipitation-flotation process of the latter will be the subject of a paper by F. F. Frick at the Los Angeles AIME meeting in February. *(See January 1953* MINING ENGINEERING *p. 83.)* In this process the crushed ore is scoured in revolving mills in a pulp having a pH of 2 and then deslimed. The sand portion is treated by conventional sulphide copper flotation. The slimes, containing the fine sulphide copper and most of the oxide copper pass to precipitation cells where an excess of sponge iron is added to the pulp. The precipitated copper, together with the fine sulphide copper, is then recovered by flotation in an acid circuit. Compared to previous methods in which tin cans were used on the precipitant, the use of excess sponge iron prevents resolution of the copper, or causes reprecipitation of what does go back into solution in the flotation cells. The excess sponge iron is recovered from the flotation tailings by Crockett magnetic separators.

Chuquicamata and Greater Butte together are scheduled to increase copper production by about 95,000 tons annually by 1953. An additional 30,000 tons of copper yearly is expected to be produced from Anaconda's new leaching plant at Yerington, Nev., by the end of 1953.

Of equal projected daily capacity to Chuquicamata will be San Manuel's new concentrator near Tiger, Ariz., in which 30,000 tons of ore per day will be crushed in two stages and ground in open-circuit rod mills and closed circuit ball mills. A copper-molybdenum bulk-flotation rougher concentrate will be reground, cleaned, and retreated for production of copper and molybdenum concentrates. Moly concentrates will be shipped, and copper concentrates will be smelted on the site.

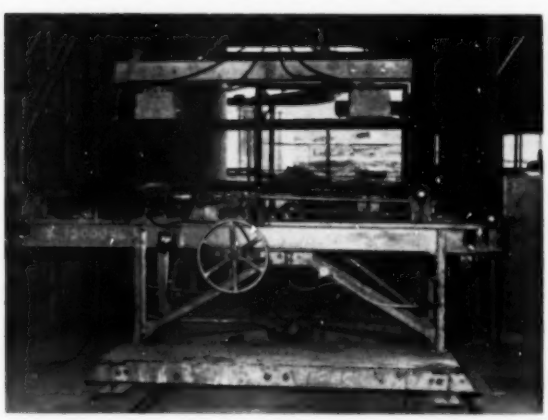
Construction of the new concentrator of Copper Range's new White Pine mill and smelter in northern Michigan was well under way at the end of 1952. With an initial capacity of 18,000 tons per day of low-grade chalcocite ore, this concentrator will employ jaw crushing underground to 8 in., conveying to surface where reduction to $-\frac{3}{8}$ in. will be effected in two stages of Symons cone crushers, followed by grinding in single stage closed-circuit ball mills preceding flotation. Flotation will produce a primary rougher concentrate and the rougher tailing will be cyclone classified. Slime portion from this separation will be discarded and sand portion refloated and reground in 8x22-ft tube mills operating in closed-circuit with cyclones. Reground product and the primary rougher concentrate will be retreated for the production of final copper concentrate for the adjacent smelter.

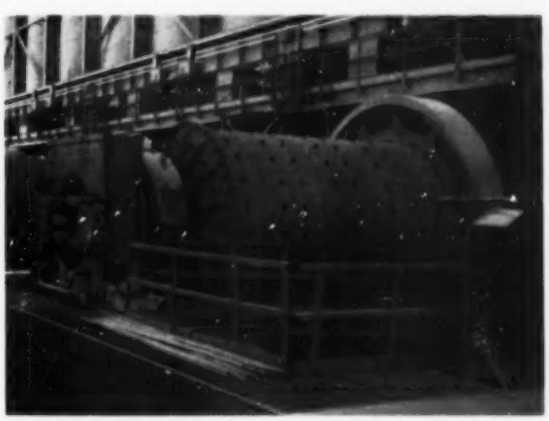
Concentrate thickener and filter plant at Chuquicamata's new Sulphide plant which started operation in 1952.

The new mill construction of Phelps-Dodge at Bisbee was started with a planned capacity of 15,000 tons per day from the Lavender Pit. Start of this operation is not scheduled before 1954.

Completion of the new Silver Bell mill of A.S.&R. is scheduled for early 1953 with a capacity of 7500 tons per day of porphry copper ore. Primary crushing will be by gyratory followed by two stages of fine crushing in Symons cone crushers Grinding will be single-stage in closed-circuit ball mills with duplex spiral classifiers. Flotation will produce a rougher concentrate which will be classified in a hydroseparator and the coarse fraction reground in ball mills in closed circuit with Dorrclones and then cleaned.

Among the new lead-zinc concentrators is that of the Van Stone mill of AS&R near Northport, Wash. with a capacity of 1000 tons per day. Primary crushing in a jaw crusher is followed by reduction in shorthead to $\frac{1}{2}$ in. Grinding is single stage in ball mills with closed-circuit rake classifiers. Flotation





Chuquicamata Sulphide plant uses 10x14-ft rod mills in open circuit. Left—Rod charging machine with loading magnets above. Concentrator was marked by simplicity in design—attention to details of materials handling.

is conventional. In the zinc circuit, middling will be reground in a ball mill in closed circuit with Dorr-clones.

The new Sink-Float plant of St. Joseph Lead Co. at Hayden Creek, Mo. was started in September. This plant uses the "H & H" galena medium process to treat 2000 tons per day. Separation is at −1¼ in. +6 mesh. Barren granite with a gravity of 2.4 to 2.6 is discarded and mineralized dolomite with a gravity of plus 2.85 is recovered at approximately a 2:1 ratio of concentration.

Among other new lead-zinc mills either starting or projected were AS&R's 200 ton capacity Keystone mill in Colorado and their Chilete mill in northern Peru of the same size. Consolidated Mining & Smelting Co. was building new mills at their H. B. mine near Salmo, B. C., and their Bluebell mine at Riondel, B. C. Pend Oreille Mines & Metals Co. started their second 800 ton unit and are constructing a third unit of the same size.

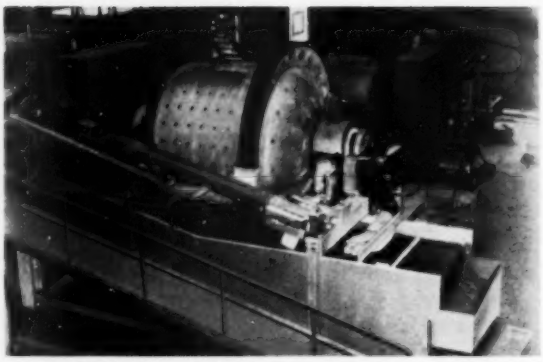
The Westmoreland Manganese Corp. in Arkansas will treat 4x¼ in. manganese ore by heavy media. Kaiser Aluminum and Chemical Co. started their dolomite plant using heavy media and St. Lawrence Fluorspar, Inc. will separate fluorspar by the same method.

Along with the plans for some of the world's biggest concentrators were announcements of some of the world's biggest milling equipment. Nordberg installed their world's biggest primary gyratory crusher, weighing well over 1 million pounds at Climax. It has a 60 in. feed opening and is approximately 27 ft high with a diameter of 19 ft. Allis-Chalmers is now building what appears to be an even larger one for Reserve Mining's Babbitt plant, capable of reducing run-of-mine ore from 5 ft 10 in. top size and standing 34 ft high with a 21 ft 8 in. diam. A 9½x12-ft peripheral discharge rod mill, also manufactured by Allis-Chalmers, and thought to be the largest mill of this type, was installed at the Bunker Hill & Sullivan Smelter. Western Machinery Co. is now building 84 in. diam simplex spiral classifiers. These, scheduled for use at Western Mining Company's West Hill mine near Colerain, Minn., are the largest simplex spirals built to date.

Grinding

An article of this kind should not only record history over the past year but attempt to indicate trends. Trend in grinding appears to still be a subject for a lot of discussion and a lot of ideas. Rod mills to take the place of fine crushers, mills of larger diameter and of higher speed, and mills using rock for grinding media were all subjects for a great deal of thought.

Among pioneers in the field were Myers at Tennessee, Garms at Hayden and Banks at Sullivan in their open circuit rod mill crushing flowsheets. Willard, of Mine and Smelter Supply Co. states "Per ton of feed, as compared to fine crushing, rod mills will figure out about the same, but the advantage the rod mill has is it produces so much finished product in open-circuit, and it does the work wet. When you take into consideration the cost of preparing finished feed in the rod mill as against fine crushers with their dry operation, dust, screens, and conveyors or elevators, there isn't any comparison in cost of the two operations". If this is true, then certainly the same is true of dry crushing rolls vs rod mills as well. Stockett of the St. Joseph Lead Co. reports that at their Federal mill, they replaced



Pend Oreille Mines & Metals Co. completed second 800-ton capacity section in 1952, and started construction of third section.

six sets of 48x24-in. dry rolls with five 9x12-ft wet open-circuit rod mills operating at 62 pct of critical. Each mill grinds 3500 tons per day of 5 pct on 1-in. feed to 30 pct on 14-mesh discharge. Yerington will use 5x10-ft open end rod mills. Oliver at Mountain Iron, Minn., will use 10x12-ft open end rod mills, and Greater Butte will use 9x12-ft mills of the same type. At Butte these rod mills will have replaced their old rolls, screens, elevators, and fine crushers.

Speed of mills is still the subject of a lot of discussion. Apparently there isn't any question about increasing the capacity of mills with higher speeds but there is a question of economy. While Consolidated is noted for their so-called high-speed rod mill, and Hayden has remained in the conventional class, it is now rumored that the latter, with harder ore, plan to increase their speed. Most of the new installations, however, will operate at normal speeds, in the 70's.

Ball mills going into the new concentrators have apparently reached their maximum diameter. Twelve feet is about the largest that can be shipped on a railroad car and still leave required clearances in most sections of the country. It is significant, however, the large number of these large mills that are going in. White Pine will use 12 ft 6 in. ID by 13-ft low pulp level mills driven by 1500-hp synchronous motors, probably the largest to date. Oliver will use 10x14-ft and Bisbee 10x10-ft, ball mills. Anaconda in their Grants, New Mexico Uranium operation will use a 5x10-ft rod mill and a 5x12-ft ball mill.

Grinding Theory

Following Crocker's work at Lake Shore on rock grinding, the St. Helena Mill in Africa started recently. This mill has four rod mills grinding to 20-mesh followed by rock grinding tube mills. Also at Tate, Georgia, several Hardinge mills are grinding with lump marble as a media. Lewis, at Tennessee Copper has dumped the balls out of a 5x10-mill, filled it with minus 3 in. rocks, and runs the mill at 90 pct critical speed. Reports are good. Jack Myers, who has undoubtedly done as much real thinking about grinding as anyone, thinks that such a grinding flow-sheet really has possibilities. It seems to the writer that capital cost of equipment vs capacity is at least one of the governing criteria. In these days of taxes, one may be able to write off higher operating costs easier than higher investments.

In grinding theory, Bond's "Third Theory of Comminution" was a real contribution. It has now

been extended to cover the economics of crushing, metal wear, dry versus wet grinding, volume of the grinding charge, pulp dilution, mill speeds, grinding media size distribution and mill diameter and length. To quote Myers: "Some twenty years or more from now, we will all look back and realize that the Third Theory by Bond was the turning point between what is now and the past as against the basic understanding of what controls comminution and the inherent economics resulting therefrom. Probably a better way to put it would be to say analyze comminution.

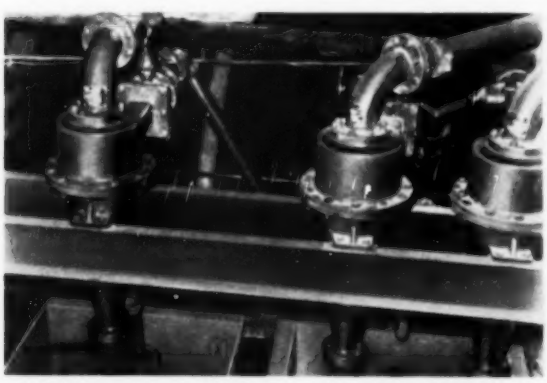
"The AIME members, as a whole, are going to find Bond's formula hard to understand and apply. Since the formula is based upon averages, it must always be borne in mind that known facts must be compensated for. It will pay anyone to learn how to use it, but it will take time and hard work. We all loved Kick and Rittenger because they never gave us a handle to their ideas. What did they do for operators?

"Dr. Robert's "Theory of Probability" clearly pins most of our "overgrinding" troubles on sorry classification. This theoretical matter is another one of those priceless contributions that has gone by the board with our operators. Free settling classifiers have got to go. Because of our lack of understanding about such things, we remain gullible to the broken record chant that fast passage through the mill will solve our overgrinding troubles.

"The Bond theory clearly shows the weakness of our grinding circuits in vogue today. The Schuman postulate or law fails to take effect until after the 80 pct passing size line appears on the log curves. Straightening out the curve of flotation feeds above the 80 pct line (or other comminuted products) is the future of grinding. We must look to hydraulic classification as it has to be the answer to this. The hydroscillator is a major step in the right direction on this score. If history repeats itself, and it usually does, other manufacturers will develop machines to accomplish the same thing."

Flotation

Aside from the new concentrators being designed or constructed, Utah Copper is modernizing. While handling some 32 million tons of ore through the Magna and Arthur mills during 1952, they started a complete remodeling job. The 56-in. cells at the Arthur mill are being replaced by 720 larger cells. At the Magna, a series of new cells will be added to treat the current tailing.



Cyclones proved versatility; were used to close mill circuits, to dewater tailing for mine fill, to deslime return water.

In Colombia, elemental sulphur is being recovered by flotation. The ground ore is autoclaved, quenched with cold water, and screened for removal of the coalesced sulphur. Screen undersize passes to the flotation cells. Flotation concentrate is combined with screen oversize, melted, and filtered to obtain a product of high purity.

The Vermont Copper Co. started a new flotation unit for recovery of pyrrhotite from copper tailings. The concentrate is roasted in a fluo-solids reactor to produce SO_2 for paper manufacture. Three new plants are now using flotation for upgrading glass sand and coal flotation continues to expand with several new plants or expansions of existing ones.

Among the new flotation reagents, Dow's "Dowfroth", was being tested by a great many mining companies throughout the world. It is a completely water-soluble, non-collecting frothing agent for the frothing of both sulphide and non-sulphide minerals. Cyanamid's 800 series promoters for non-sulphides found new applications. They will be used in commercial iron ore flotation and are being extensively used for flotation of such minerals as iron oxides, ilmenite, garnet, tourmaline, biotite, and in the purification of glass sands. Two plants in Sardinia and one in Italy are using alkyl or aryl mercaptons or amines in the difficult problem of floating zinc carbonate ores.

Heavy Media Separation

Each year sees more and more installations of this process until now the compilation of existing plants or those under construction shows them to be treating almost all common minerals. New plants in 1952 included those for coal, iron ore, lead, zinc, tin, pyrite, diamondiferous ground, chromite, gypsum, dolomite, uranium, potash and fluorspar. Separatory vessels included cones, drums, spirals, and trough types employing flight conveyor for sink removal. At the present time there are 146 plants using heavy media separation either operating or under construction.

DSM Cyclone Separator

Early pilot plant work with the Dutch State Mines Cyclone Separator on fine iron ore by M. A. Hanna Co. was followed up by a commercial size plant which was operated during 1951 and 1952 operating seasons. A 50 ton per hr pilot plant was also in operation during 1952 at the Holman Cliffs Mine by the Mesaba-Cliffs Mining Co. Additional commercial size plants, under design or construction, to start during the 1953 operating season, include two for the Hill Trumbull and Hawkins Mines of Cleveland-Cliffs; one for the Hill Annex plant of Jones & Laughlin Steel Co.; and one for the Harrison plant of M. A. Hanna Co. Three other mining companies are planning Dutch State Mines installations for the 1953 season, as a result of the favorable experience of the pioneer installations.

Several mining companies in this country are reported to be planning important installations for treatment of base metal and manganese ores. With the background of experience gained in the treatment of iron ore, the potentialities of this interesting new process are becoming more evident and it seems reasonable to expect that more rapid progress in the adoption of cyclone separation will take place in the future.

Gravity Concentration

With all the new processes of mineral dressing, one is inclined to relegate the old processes of jigging and tabling to the past with vanners and buddles. Such is not the case with respect to treatment of the non-metallic minerals. One prominent table manufacturer reports increasing use of tables over the past ten years with the curve still rising. The modernized table, of course, has rubber cover, cemented-on rubber riffles, anti-friction bearing head motion, etc. With non-sulphide ores not amenable to flotation, and with coarse-metallic ores like those of the Michigan native coppers, the jigs and the tables may always be with us.

Humphreys spiral concentrators continue to be used in many phases of mineral dressing, particularly in the fine iron ore and industrial minerals field. New installations during the year included several on iron ore, barite, chromite, mica, tungsten, and the so-called heavy minerals (ilmenite, zircon, rutile, etc.)

New Processes

Chemical Metallurgy. Falconer of American Cyanamid contributes the following on this new process: "Chemical Construction Corp., a subsidiary of American Cyanamid Co., has developed a series of techniques to recover high purity metal powders and compounds of metals from ore, concentrate and matte as well as from copper blister and scrap. To date, these techniques have been piloted and developed for commercial application to the important ores or concentrates of copper, nickel and cobalt. Approaching this status also are processes for the treatment of low-grade manganese ores, refractory gold-arsenopyrite concentrates and a number of other complex ores. The basic Chemico technique comprises three principal operations—leaching, separations, and reductions. The main steps are carried out at elevated temperatures and pressures in autoclaves and involve treatment of slurries and aqueous—acidic or alkaline—solutions with oxidizing or reducing gases.

"Two plants employing these Chemico processes are under construction, for Sherritt-Gordon Mines Ltd. in Canada, and for National Lead Co. near Fredericktown, Mo. for production of copper, cobalt, and nickel powders. A third plant is now in operation by Howe Sound Mining Co. at Garfield, Utah to treat cobalt concentrate from its Blackbird mine at Cobalt, Idaho."

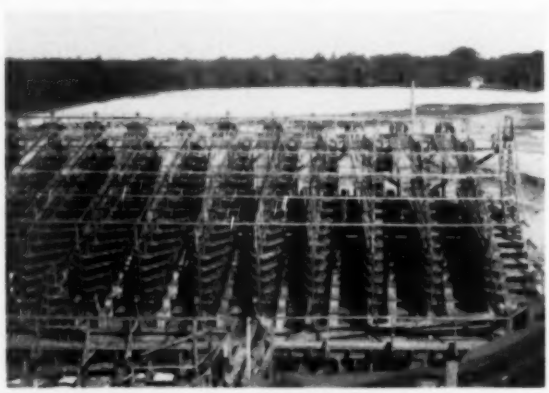
U. S. Vanadium Co. has installed a new process for treating uranium ore at its Uravan, Colo. mill. Specially developed for treating high-lime uranium ores, it is believed to be the most efficient process yet developed for the recovery of both uranium and vanadium.

While slag fuming of current and old lead smelter slags has been practiced several years for zinc and lead recovery, an interesting development is the addition of a limited amount of non-sulphide lead-zinc ores directly to the hot slag bath. Zinc oxide is reduced and reoxidized and recovered along with the zinc oxide in the slag. The tonnage of such addition is reported to be limited to 15 pct of the hot slag treated, and the analyses of the crude ore treated must be suitable to the process in which the lead is recovered as a low value oxide which has to be retreated at the lead smelter.

Titanium Progress. Byler of The Merrill Co., contributes the following: "During 1952 there has been a tremendous surge of interest and activity in the production of ductile titanium, which has been induced by greater appreciation of the commercial possibilities of the metal for special applications, and by the requirements of the Armed Services.

U. S. Vanadium Co. installed new process for treating high-lime uranium ores at its Uravan, Colo., mill.

"Some 100,000 tons of ilmenite are being recovered annually by DuPont from Florida beach sands, which contain less than 2 pct ilmenite, and are concentrated by Humphrey Spirals and electro-magnetic and high intensity magnetic separators. The Bureau of Mines reports that it has successfully developed a flotation treatment for ore containing brookite in which a 6 pct ore is concentrated by special procedure involving pretreatment by an alkaline blunge and substantially complete desliming of the ground ore, following which the mineral is activated with a heavy metal salt and floated with a soluble soap. Final concentration is effected with a cationic reagent in an acid circuit. A 60.6 pct recovery is said to be obtained in a concentrate containing 92.8 pct titanium oxide, 1.4 pct silica, and 1.6 pct iron. The Bureau of Mines also reported success in treating titaniferous magnetite ores from Iron Mountain, Wyo., by a roast and sodium carbonate leach which removes vanadium in an 80 pct V_2O_5 cake, the leach residues then being smelted with coke in a graphite-lined furnace to produce a high titanium slag.



Florida beach sands yield some 100,000 tons of ilmenite annually for DuPont in plant using spirals, magnetic separators.

"The large operation at Sorel, Quebec, by Kennecott and New Jersey Zinc has almost reached full production, and it is expected that by the end of 1952 there will be five furnaces in operation processing 1500 tons of ore per day. The ore contains about 40 pct iron and 35 pct titanium dioxide, and the furnace operation gives a slag containing about 72 pct titanium dioxide.

"Greatly expanded research programs in this country and abroad, both applied and fundamental, have been implemented during 1952 to provide data and answers to the very difficult technical problems involved in reducing titanium oxide to ductile metal. In this country the Office of Naval Research is sponsoring a large program of fundamental research on titanium. Little information of specific nature is available on the results from applied research which is being carried on by an impressive number of Companies engaged in efforts to develop a cheap, efficient, large-scale production method for the metal. Methods at present being pilot-planted include electrolytic reduction of fused salts, direct reduction of the titanium oxide by calcium or magnesium, and methods such as that of the Kroll Process, at present in production operation, in which a halogen of titanium is reduced by liquid magnesium. Some measure of the demand for titanium is indicated by the fact that DMPA has reportedly signed contracts this year with Titanium Metals Corporation and DuPont for the production of 7500 tons of the metal per year, with provision for protecting against early obsolescence of the process installed."

Materials Handling

Interesting developments in this field include the perfection of the sheet steel rubber-covered conveyor belt introduced in Sweden a couple of years ago. The B. F. Goodrich Co. is working on the introduction of this for high tensile applications in this country.

The Streeter-Amet Co. of Chicago has adapted the Baldwin Locomotive Work's Strain Gauge for weighing applications, and track scales, weigh hoppers, and related items have been or are now being built utilizing this accurate low maintenance principle.

Capacity of the new vessels for transporting iron ore from Liberia, Chile and Venezuela to this country is considerably larger than that of the Great Lakes ore boats, having a maximum cargo of 40,000 tons per vessel. Incidentally, a ship of this size has about the same displacement as the new liner S. S. United States.

Screening

Nordberg Manufacturing Company has come out with a heavy-duty vibrating grizzly for primary scalping applications. Both Nordberg, Allis-Chalmers and Tyler now offer rod deck screen surface.

Electric heat of screens has been accepted for some applications but is limited by the complexity of the electrical installation and the problem of adjusting the device to compensate for varying resistance in different screen surfaces. The gas heated screen seems to be a more easily controlled device for handling sticky material. With the electrically heated screens, however, the Deister Concentrator Co. has now equipped their Leahy Screen with their new Flex Elex design which is said to correct the weaker points of previous designs; a 4x7-ft single surface screen contains a 15 kva heavy duty type air cooled transformer mounted directly on the screen frame.

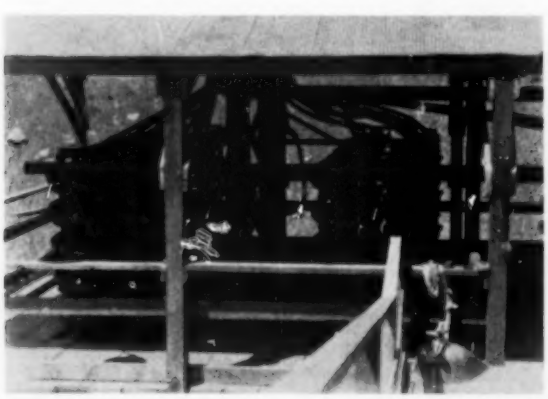
Pyrolysis

The Double Width Sintering Machine built by the American Ore Reclamation Co. has completed its first year of operation. It shows promise of lowering some sintering costs. New discharge track arrangements for sintering machines have come on the market to minimize rubbing of pallets at the ends of the machines. Much progress has been made by operators in controlling the mixing of feed to sintering machines with resultant improvement in product quality and capacity.

Sinter testing has made long strides. Several companies have set up their own control labs recently, and a Fellowship has been established at the Mellon Institute in Pittsburgh to study the factors affecting sinter machine performance. As a result of this activity, scientific quality control is entering the sintering field.

Research

Kennecott Copper is building a new research laboratory on the University of Utah campus. This laboratory, to employ approximately 50 technicians, will cost $1.25 million. Work will be on a variety of problems associated with mining, milling, smelting, and refining.



Humphreys Spirals found wide application, ranging from ilmenite recovery on beach sands to treatment of stockpiled intermediate-grade Iron Range ores. Installations varied from extensive banks of units, opposite page, to smaller, compact plants, like Minnesota iron ore beneficiation plant shown left and right above.

Industrial Minerals

by Ian Campbell

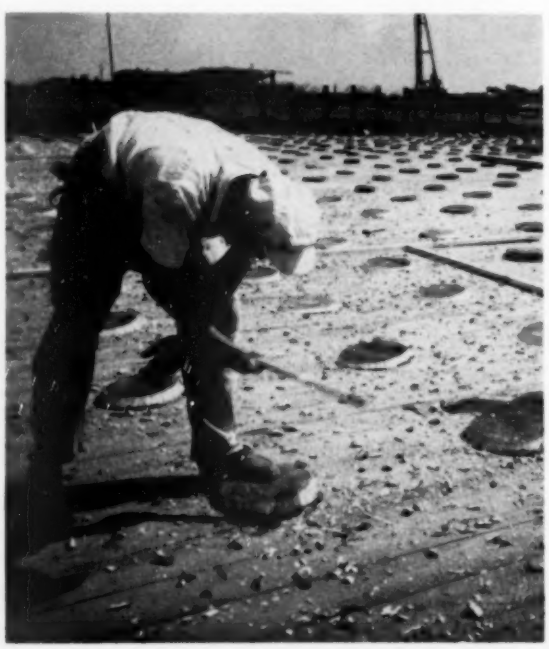
THE year 1952 was marked by several new all-time highs in industrial mineral production; by an easing of the critical situation with respect such minerals as fluorspar and sulphur; by important production of asbestos, lithium, and rare earths; by the perfecting of new products which will place new demands upon industrial mineral supplies, such as "Fiberfrax", and the finding of new uses for old minerals, such as wollastonite; by continuation of basic and applied research; and publication of a notable study of the national mineral economy, viz., the "Paley Report".

Although as this review is being written no total production figures for 1952 are available, it is clear that producers of most industrial minerals have enjoyed a good year, and many minerals may show new production highs when the final figures are in. Barite, beryl, boron minerals, bromine, lithium minerals, rare earths and salt are likely to be in this category. The continued high pace in building and construction has placed ever heavier demands on cement and on sand, gravel, and aggregates of all types. Some of these are likely to show new highs.

Improved Fluorspar Supply

At the beginning of the year, fluorspar was in short supply, and neither new domestic sources nor increased supplies from domestic producers appeared to be adequate to meet anticipated demands of the steel industry and other large consumers. At the year's end, this situation was improved, principally as the result of development of areas in the State of Coahuila in Northern Mexico. Here, three areas, Encandado, El Tule, and Saltillo shipped in 1952 some 150,000 tons of metallurgical grade fluorspar to the United States. A large share of this has come from many small individual surface operations, particularly in the Encandado and El Tule areas, where the fluorspar occurs as replacement beds in relatively flat-lying Cretaceous limestone (probably the equivalent of the Edwards limestone). In the Saltillo area, deposits are reported to consist chiefly of steep-dipping veins. As an indication of the generally high grade of the deposits, is the statement that acid-grade fluorspar can be obtained merely by hand-jigging. Several U. S. companies are interested in the district, and American Smelting and Refining Co., is reported to have started construction of a flotation plant which is expected to go into production early in 1953. Estimates of reserves in the district are still largely speculative, but figures of two to three million tons seem not unreasonable. Unquestionably the rapid development of this district has averted what might have been a serious shortage of this important industrial mineral, and this, with current domestic developments, gives promise that the situation should be eased for some time to come.

Several new domestic fluorspar installations are reported to have been completed in 1952 or are in process of completion. A new flotation mill was installed by the Kaiser Aluminum & Chemical Corp. near Fallon, Nev. The chief source of the mill feed will be the Baxter fluorspar mine, which the corporation acquired from H. W. Gould & Co. early in the year. The Ozark Mahoning Division of Mahoning Mining Co. at Cowdrey, Colo. started in June a production of 250 tons per day in its new mill. Mining is to be both open cut and underground with some dump ore being blended in. Much of the production will be shipped to the new aluminum plant of Reynolds Metals at Corpus Christi. St. Lawrence Fluorspar, Inc., is expanding its milling facilities near the company mine in Newfoundland, and is constructing a flotation mill at Wilmington, Del. Still another new fluorspar development is a proposed 250 or 400 ton mill to be built by Pennsylvania Salt Manufacturing Co. at Mexico, Ky., where the U. S. Steel Corp. has recently completed a small fluorspar plant. The Aluminum Ore Co. is expanding its facilities for producing artificial cryolite at its East St. Louis, Ill., plant.



IAN CAMPBELL is Chairman of the Industrial Minerals Division AIME, and Executive Officer of the Division of the Geological Sciences at the California Institute of Technology.

Sulphur

Equally favorable from the point of our domestic economy—and also of our foreign relations—has been the improvement in the sulphur supply. In this case, the improvement has resulted, not so much from development within a single district, as from a large number of factors and sources. A significant amount has come from new development, and expansion, of Frasch plants. Either in production or soon to come in are Starks Dome, developed by the Jefferson Lake Sulphur Co. and Spindletop[1] Dome, developed by the Texas Gulf Sulphur Co. The latter company is also expanding at Moss Bluff Dome. Freeport Sulphur Co. is developing Bay Ste. Elaine Dome, Garden Island Dome and probably Nash Dome. At Garden Island Dome reserves have been increased and may be as much as 20 million tons. Developments in the Isthmus of Tehuantepec offer promise of additional supply, but are not yet far enough advanced to permit tonnage estimates. Here, amongst others, the Pan-American Sulphur Co. is said to have some five million tons producible; and the Mexican Gulf Sulphur Co., has a plant already under construction.

[1] *It will be of interest to recall that it was Captain Lucas' discovery of oil at Spindletop a half-century ago that, by providing an economical source of fuel, made the Frasch venture at Sulphur Dome, La., a commercial success. With production of sulphur from Spindletop itself, one might say that the sulphur cycle is now complete.*

Although currently about 85 pct of this country's supply and about 50 pct of the world supply is obtained from mining of elemental sulphur, there is increasing recognition of the fact that Frasch-process sulphur cannot meet the increasing demands forever. Hence industry is turning gradually toward other sources. Sour natural gases, water gas, and coke oven gas are being increasingly utilized as a domestic source. For example, Hancock Chemical plant in Los Angeles has within the past year doubled its capacity for handling flue gases from nearby catalytic petroleum refineries, and is now producing 150 tons per day of elemental sulphur. Metallurgical gases from sulphide smelters are being increasingly exploited. The Bunker Hill & Sullivan Mining Co. has started construction on a $5 million sulphuric acid converter (due for completion in January, 1954) to utilize stack gases from the zinc section at the Bunker Hill smelter near Kellogg, Idaho. The zinc roasters are being revamped to produce a high SO_2 effluent gas for acid production. A daily production of 250 to 300 tons of sulphuric acid is expected. Most of this will be used in the production of phosphate fertilizers.

In Canada, with her rapidly expanding industrial needs, the short supply of elemental sulphur has led to a number of important developments. Early in the year Shell Oil Co. of Canada began production of elemental sulphur from sour natural gas at Jumping Pound, Alberta and is currently producing at the rate of 11,000 tons per year. During the summer, Royalite Oil Co. at Turner Valley, Alberta, began production of sulphur from sour natural gas at the rate of 10,000 tons per year. The sulphur from both of these plants is exceptionally pure. Canadian Industries Ltd. has begun the marketing of liquid sulphur dioxide from the gases of the new oxygen flash-smelting process of the International Nickel Co. at Copper Cliff, Ont. When this new plant is in full operation it will be producing about 90,000 tons of liquid sulphur dioxide each year. This is equivalent to 45,000 tons of sulphur. It will be used mostly by sulphite pulp mills in Ontario and Quebec to replace imported sulphur. Tests made by Abitibi Power and Paper Co. proved that the pulp mills may be adapted easily to the use of liquid sulphur dioxide. Consolidated Mining and Smelting Co. has for years obtained its very large requirements of sulphuric acid for fertilizer manufacture from the gases of its Trail, B. C. smelter. In connection with its new fertilizer plant at Kimberley a new sulphuric acid plant is to be built to produce 300 tons of sulphuric acid a day from pyrrhotite tailings from the Sullivan mine. During the years 1935-43 the company recovered elemental sulphur from smelter gas at Trail. Eight Canadian sulphite pulp

World's largest single sulphur development in 20 years is being built by Freeport Sulphur Co. at Garden Island Bay, La., to mine 500,000 long tons of sulphur per year. RIGHT—An early stage in construction of the multi-million dollar plant. A half-million cu yds of fill were required for the plant site alone, and thousands of piles had to be driven for foundations. The Garden Island plant is due for completion about the end of 1953. LEFT—Workmen tapering some of the 2163 fir pilings driven 85 to 90 ft into the earth to provide firm foundation for main plant. Wooden floor will be covered by 16-in. concrete mat, which in turn will serve to support a series of concrete cells. Atop these cells, 16 ft above Gulf level, the main plant floor will be built.

mills have taken steps to insure the supply of sulphur dioxide vital to their needs by installing equipment to burn domestic pyrite instead of imported sulphur. This switch to pyrite coupled with the use of liquid sulphur dioxide and Alberta sulphur will replace about 100,000 tons of imported sulphur a year. Noranda Mines Ltd. has plans, not yet put into effect, to build a plant in the Niagara Peninsula to roast 300 tons of pyrite daily for the production of sintered iron oxide and, at the same time, to produce 50 tons of elemental sulphur and 300 tons of sulphuric acid a day. Aluminum Co. of Canada has just completed a plant at Arvida to make 45,000 tons of sulphuric acid a year from gas derived from the roasting of zinc concentrates from the Barvue mine. Nichols Chemical Co. has doubled the production of sulphuric acid from pyrite at its Valleyfield, P. Q. plant and is now producing 100,000 tons a year.

Overseas, pyrites and more recently gypsum and anhydrite have been utilized as sources of sulphuric acid. A British company is reported to have concluded, after a survey made this year of the possibilities of setting up a sulphuric-acid-from-anhydrite plant in east-central United States, that such a venture could not yet be made competitive with established sources of domestic supply. Nevertheless our wide-spread deposits of gypsum and anhydrite constitute a vast potential reserve.

Asbestos

In asbestos, a mineral of which we seem never to have enough in the higher grades, the picture was markedly brightened in 1952. The most notable event is the development of the new chrysotile property at McDame Mountain, British Columbia, by Cassiar Asbestos Corp., a subsidiary of Conwest Exploration Co., Ltd. The deposit is said to contain an unusually high percentage of asbestos of spinning grade relatively free from iron. Loose fiber is available on the surface of a talus slope. A new mill was virtually completed at the end of 1952, and production of several thousand tons a year of high-grade fiber is anticipated. The fiber is said to meet stockpile specifications for low-iron asbestos for electrical cable coverings, and is the first North American asbestos, in any quantity, to meet these exacting specifications. Even more important is the circumstance that British Columbia is now to be numbered among the asbestos-producing provinces. Indeed, the well known statement that "asbestos production in Canada is confined to the Eastern Townships of Quebec" must now be revised—the more so in that production is also under way in northern Ontario and Newfoundland. The harsh-fibered asbestos near Matheson, Ont., is under development by Canadian Johns-Manville Co. to supply the ballooning market for asbestos-cement products. And in Newfoundland a mill is being built by Newfoundland Asbestos Ltd., to process good-quality fiber from a small deposit of chrysotile at Lewis Brook on the west coast.

While these developments have strengthened Canada's long-dominant position as the world's principal source of asbestos, important developments have also been taking place in the old established Quebec area. New properties are being developed, new mills are being built, and others are being modernized and enlarged. Asbestos Corp. is developing a new ore body—the Normandie—at Vimy Ridge and is building a new mill there with a capacity of 4,800 tons of rock per day. Most of the production

Looking north from Cassiar, B. C., toward asbestos deposit on the western slope of the mountain.

will be shingle and paper stock. Johnsons' Co. is building a new mill at its Black Lake, P. Q., property with a capacity of 4,000 tons of rock daily and expects to have it in operation early in 1953. Canadian Johns-Manville Co. is proceeding with plans for an entirely new mill to replace the present mill at Asbestos, P. Q. Most of the production at Asbestos is now coming from underground block caving operations. Dominion Asbestos Mines Ltd. is building a mill of 2,200 tons daily capacity at Saint Adrien, P. Q. The construction schedule calls for its completion early in 1953. United Asbestos Corp. has completed arrangements with American Smelting and Refining Co. of New York for the further developing of its Black Lake property.

In the United States, spurred by efforts of the DMPA to improve domestic supply of spinning fiber grades, developments are under way in Arizona, California, Montana, and Vermont. These are still too new to evaluate, but they are unlikely greatly to change the size of the demand we place upon our good neighbor to the north. The Johns-Manville Corp. at Tilton, N. H., and Raybestos-Manhattan, Inc. at Manheim, Pa., are continuing research on making low-iron insulating papers and tapes from Canadian asbestos to be used as substitutes for the low-iron chrysotile obtainable in decreasing quantities from the Shebani area of Southern Rhodesia.

Rare Earth Minerals

Rare earth minerals are coming into increasing demand, not only for their cerium content, with its important applications in special steel alloys and their military applications, but also because of an increasing interest in thorium. In Idaho, three dredges have been operating on monazite placers north of the Boise basin. In Southern California, the unique bastnaesite deposit acquired two years ago by the Molybdenum Corp. of America has been further developed, with encouraging results as to reserves. The newly completed mill went into operation in May, and is currently handling more than 150 tons of bastnaesite ore per day, and it is expected that this figure will be brought up to 200 and 300 tons per day in the coming year. Recently a chemical plant has been added to aid in the recovery. Eventually this development promises to be our largest domestic source of the rare earths. One of the principal gangue minerals of the bastnaesite is barite, and currently the barite tailings are being stock-

Asbestos veins in serpentine rock. It is hoped that Cassiar asbestos will meet exacting specifications.

piled against the time when beneficiation may be possible. In South Africa, in the Transvaal, the Anglo-American Co., is reported to be going into production shortly with a plant capable of handling 10,000 tons annually of rare earths. These are reported to be of high thorium content.

Few industrial minerals have seen such an upward spiralling demand in the past decade as has the lithium group. Yet, looking ahead to 1956, the National Production Authority currently estimates a requirement in that year of 10 million lb of lithium carbonate equivalent. To meet the immediate and anticipated need for lithium products there have been several major developments in the past year. The Foote Mineral Co., which late in 1951 was milling 350 tons per day of spodumene-bearing pegmatite at its new Kings Mountain, N. C. plant, is now expanding this operation to handle 1,000 tons per day. The spodumene is recovered by flotation, and in the process feldspar, quartz, columbite, mica, and tin concentrates may eventually be separated in commercial amounts. Simultaneously with this expansion, Foote is constructing a new plant at Sunbright, Va., to utilize local limestone and coal in processing spodumene concentrates from Kings Mountain. A 10x340 ft kiln will be used in processing the lithium ore. This is the first time a kiln has been installed in a flowsheet of this type. Both of these developments are expected to be complete by mid-1953. Across the continent, at Searles Lake, Calif., where American Potash and Chemical Corp. has been producing lithium concentrates from their evaporative process for the past fifteen years, the corporation has completed a plant to convert the concentrates to lithium carbonate, with phosphoric acid as a by-product. Corrosion problems have been solved, and currently all of the lithium concentrates are being processed to lithium carbonate. In the Black Hills, S. Dak. district, Metalloy Corp. (subsidiary of Lithium Corp. of America) completed a new flotation plant at Hill City, and is recovering spodumene from Black Hills pegmatites. Two other mills in the Black Hills are being rehabilitated, Tinton Tin Co. and Holy Terror Gold Mining Co., and will ship spodumene concentrates to the Maywood Chemical Works.

New Developments and Uses

Perhaps no other factor in the industrial minerals field provides more challenge, and stimulus, than the perfecting of a new mineral product, or the discovery of a new and unsuspected use for a hitherto relatively valueless mineral. The year 1952 has seen its quota of such developments, even if sufficient time has not elapsed fully to evaluate the potentialities. Illustrative of such developments is "Fiberfrax", a ceramic fiber developed by the Carborundum Co. at its Niagara Falls, N. Y., plant. Fiberfrax contains about equal parts of alumina and silica with 1 pct boric acid or 0.5 pct soda ash and is produced by melting in an electric furnace and blowing the melt. The product is a white cotton-like fiber of fine diameter, about 0.0002 in. The material can stand continuous temperatures of 3000°F; can be formed into brick, board, or paper; and can be used as chemical filter. Present production is around 15 tons per day, with 50 tons per day expected by 1954. Illustrating the second case, new use of an "old" mineral, is wollastonite, to which attention was first called in 1951. In the spring of 1952 Godfrey L. Cabot Inc. of Boston began construction of a new plant near Willsboro, N. Y., for increased production of this mineral. There has been small production for a number of years, but the capacity of the new plant is reported to be 58,000 tons of finished product annually. The developing use of wollastonite as a paint extender and an ingredient of various ceramic products is believed to account for much of the expanding demand. The plant is due for completion in early 1953.

Adequately to review the year's results in basic and applied research in the field of the industrial minerals would deserve an entire issue of MINING ENGINEERING. Suffice that research goes on apace in the field and in many laboratories; but that much more is needed if our mineral economy is to continue to improve. As examples of the kind of programs that should some day pay large dividends might be cited: 1) A Bureau of Mines investigation of processes for recovering vanadium from western phosphates. This may make possible economic recovery of vanadium from the vast tonnages of western phosphate rock. 2) Studies of the National Bureau of Standards, which along with those of the U. S. Bureau of Mines and the Colorado School of Mines, have been advancing the synthesis of mica to the point where it is now possible to grow a synthetic phlogopite having essentially the same physical and electrical properties as natural phlogopite, except that the flexibility is somewhat less. Cost is reported to be about six times that of natural phlogopite. 3) The U. S. Geological Survey's "Mojave Project" which is concerned with mapping the basic geology of this great desert area, and is pointed particularly to better knowledge of the saline deposits therein. From this will eventually come increased knowledge of the reserves of borax, lithium, potash, soda ash, and others of the saline minerals.

In the opinion of some well-qualified mineral economists, the most important event of the year was not any new find, nor the application of an old mineral in a new use, nor the discovery of a new process—events which have high-lighted this year, as they have many preceding years of industrial mineral developments—but it was the publication of a monumental report, the "Paley Report". That this monographic report has been received with mixed feelings on the part of the mineral industry is if anything an understatement. There is not a mining journal which has not discussed it pro and con, or pro *or* con.

What the true impact of this report is to be must be left for future reviewers who can write without reference to a crystal ball. Already this much seems clear: although set up by a Democratic regime, the committee was politically non-partisan, and included some of our ablest mining men and industrialists. Whether one feels inclined to agree or disagree with the conclusions and recommendations of the report, it must be recognized that they will carry weight for some time to come. The data presented are the best available. The recognition, on the part of the Executive Branch of our government, of the importance of the mineral industry to our national economy and to our national future, should be gratifying to all who are connected with the industry. The recognition, on the part of industry, that—however much mining development in this country owes to the rugged individualism of the few—there must be some planning at a national level if we are to care for the many—and for the future—comes hard to some, more easily to others.

Certainly few would agree that we ever can, or ever should, return to a wholly *laissez faire* system in our mineral industry. The extent to which we must and can plan for the future, and the extent to which controls, whether State or Federal, or both, must be used in order to accomplish this are and should be cause for intelligent debate. Gratifying to the Industrial Mineral producer is the recognition in the Paley Report, of the desirability of maintaining depletion allowances for many nonmetallic minerals, commensurate to those that obtain amongst metallic minerals; and likewise gratifying is the plea entered in the Report "that the present limitations applicable to minerals other than oil and gas on the amount of permitted expensing of exploration costs be removed."

The foregoing discussion presents only a few of the highlights in the Industrial Minerals picture of 1952; others are briefly sketched in the commodity listings.

Commodity Listings

ABRASIVES—Industrial diamonds continued in short supply, although the critical shortage that existed earlier in the year has been partially relieved by increased imports. Development of rich placer ground is being pushed in the Belgian Congo. The production of almandite garnet is being increased. The heat-treated fine-grained fraction is a partial substitute for corundum in precision lens grinding. Practically all requirements for corundum are being filled by imports. There is little domestic production.

AGGREGATES—Demand continued heavy through most of the year for all kinds of aggregate, but with increasing emphasis in various quarters on production of lightweight types. In Canada, where currently only one plant (Cooksville, Ont.) is making coated concrete aggregate of the "haydite" type, extensive surveys have been undertaken to find additional sources of suitable raw materials. Promising deposits have been reported in Nova Scotia where for several years "foamed slag" lightweight aggregate has been in production. In Chicago, the Armour Research Foundation has announced a new ceramic product, trade-named, Kanamite, which has possibilities of becoming an important fine, lightweight aggregate for concrete, mortar, and plaster. It consists of tiny, hollow, glass-like spheres which are produced by furnace treatment of finely ground and screened clay. Available sizes range from 4 to 250 mesh, and vary in density from 17 to 25 lb per cu ft.

BERYL—Beryl is one of the strategic minerals with only a small domestic tonnage produced by hand picking and cobbing methods. The DMPA is sponsoring a Bureau of Mines investigation of methods of recovery of beryl from North Carolina spodumene ores and is negotiating for a pilot mill to recover beryl by flotation. At the Harding mine, in northern New Mexico, beryl is being produced in substantial amount, although not quite at the amazing rate that prevailed in the preceding two years. Total production over the three year period of operation will be in excess of 350 tons, putting the Harding mine in a class by itself as a domestic beryl producer. At the Beecher No. 3 property, in Custer County, S. Dak., a recent discovery has yielded significant quantities of beryl, and this district as a whole continues to be an important producer. Around 90 pct of our beryllium needs must be met by foreign imports, largely from Brazil and South Africa.

BARITE—This year has been one of high production in the barite industry, and it is predicted that the demand and use will be even higher in 1953, based on the stepped-up usage of ground barite in drilling fluids which will be necessary to keep abreast of the 1953 oil-drilling program sponsored by the Petroleum Administration for Defense. A significant portion of the proposed drilling will take place in the high-pressure fields of the Gulf Coast and California, making the use of heavy drilling mud mandatory. Moreover, the shortage of steel well-casing has promoted the use of both barite and bentonite to hold walls without pipe. In anticipation of the increased demand, two companies plan to build new fine-grinding mills of 60,000 tons annual capacity each. The Magnet Cove Barium Corp. will build at New Orleans, La., with its main sources of ore reportedly being in South and Central America. The Baroid Sales Division of National Lead Co. will erect a mill at Corpus Christi, Texas, and will get its ore from Nova Scotia for the most part. This latter company is also planning an expansion of its Malvern, Ark., plant where froth flotation methods are used. In addition, the Superbar Co. is doubling its present capacity of 60,000 tons annual production with the erection of additional fine-grinding units at its plant near Potosi, Mo. The plant will continue to utilize local ore from Washington County.

BORON MINERALS—All indications point to the boron minerals as being the newest spectacular example of material, long used in various compounds in a variety of industrial applications, and then much later finding demand as a source for the element itself. Not until 1951 was it widely recognized that elemental boron has many important uses. It had already found several applications in the atomic energy program; it is reported as being usable in jet engines, nuclear engines and rocket fuels. But

it is as a steel alloy that it is finding its most rapid employment. In 1951, more than 600,000 tons of boron steel were manufactured; some estimates place 1952 production of boron steel as high as 11 million tons. To be sure, only very small quantities of boron are required to confer desirable hardenability characteristics on steel—to the manufacturer, this is one of the advantages of boron and compensates for its still very high price—but with increasing experience in the application of this element, increasing demand is likely to come. Supplies of the raw materials, chiefly the bedded borax and kernite deposits at Boron, and the brines of Searles Lake in California, appear adequate for the immediate future.

CEMENT—In keeping with industrial expansion, the cement industry has likewise been expanding during the year, and production may reach new high levels. The Huron Portland Cement Co. has added four new kilns to the eighteen that have been operating previously. This expansion makes Huron the largest single cement plant in the United States.

CLAY—Clays of all sorts continued to be in large demand, with supply for the most part adequate. The Filtrol Corp. is continuing to produce halloysite from the Dragon Consolidated mine in Utah. Search is continuing for new supplies of halloysite of catalytic grade, but without any report thus far of discovery of commercial deposits. A new mill, with capacity of 5 tons per hour, has been constructed on the south shore of Owens Lake, Calif., for processing bleaching clays. The Apex Smelting Co. of Chicago has announced the successful completion of experiments, carried on with the cooperation of the U. S. Bureau of Mines, in direct smelting of clays for the production of aluminum-silicon alloys. The company has acquired a site for a plant at Springfield, Oregon, which will utilize high-alumina clay and hog fuel (waste wood chips) to give the charge porosity and to replace carbon as the reductant.

Pregnant with possibilities was the "First National Conference on Clay", organized by the University of California, with cooperation of various groups including AIME, and held at Berkeley in July. Clay experts from the mineral industry, from the petroleum industry, from the ceramic industry, and elsewhere assembled for three days of uninhibited discussion and free exchange of information on the most complex and versatile of nature's inorganic handiwork—the clay minerals. Steps were taken to continue such conferences under the auspices of the National Research Council.

DIATOMITE—With the Dicalite Division of the Great Lakes Carbon Corp. putting their new plant at Lompoc, Calif., into operation in April, and with the Johns-Manville Co. enlarging production facilities at its Lompoc plant, the diatomite industry was provided with facilities for an estimated production increase of some 100,000 tons per year over 1951. That the 1952 total will fall somewhat short of the 290,000 tons produced in 1951, is due wholly to the seven-month shut-down caused by a labor dispute at the Johns-Manville Lompoc plant. The long diatomite shortage emphasized the growing importance of this industrial material, and with resumption of operations at the Johns-Manville plant in October, production for the entire industry is now at the highest level on record. Dicalite Division of Great Lakes Carbon Corp., in addition to Lompoc, is operating plants near Los Angeles, Calif., in Central Oregon, and in Southern Nevada. Increasing demand for diatomite is anticipated, not only because of greater need by present users, but because of expanding markets resulting from an increasing number of new applications. Thus filtration of antibiotics is a new and rapidly growing use, and filtration and recycling of process water is coming to the front for elimination of stream pollution as well as for conservation of water.

FELDSPAR—Developments in the feldspar industry continue along the same trends shown previously in the post-World War II era. As more and more pegmatite deposits of high-quality feldspar become exhausted, and as fewer and fewer new ones are found, increasing attention is being given to flotation processes. Several plants are in operation in the eastern states, and there is some talk of locating at least one somewhere in the west. One flotation plant already is in successful operation in California, but the product is a concenfrate from beach sands.

LIME—Lime is used extensively in the chemical and other manufacturing industries, and the uptrend in industrial activity resulted in an increase of 10 pct in lime output, which may reach 8.25 million tons in 1952. This will be an all-time high record. Much research is in progress, and many articles have been written on calcining and hydrating problems.

MICA—The demand for scrap mica has been increasing steadily for most of the past decade. The market for sheet mica, however, suffered a decline at the end of the war and domestic production has

LEFT—Aerial view of Kings Mountain plant of Foote Mineral Co. RIGHT—Loading spodumene ore in pegmatite quarry at the Kings Mountain, N. C., lithium operation.

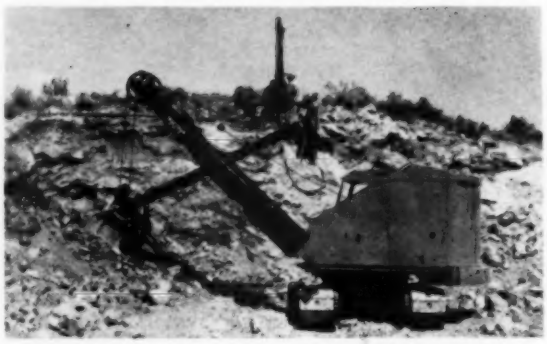
been somewhat in the doldrums for several years. Currently, though, domestic production of sheet mica is being stimulated by the government purchase program at bonus prices. Purchase depots have been opened in Spruce Pine, N. C., Franklin, N. H., and Custer, S. Dak.

PERLITE—Perlite continues to expand[1] (as indeed it should!). In the Socorro, N. M., area activities have been expanded. Other deposits in the southwest, in New Mexico, Arizona, Nevada and California are being investigated and several new ones brought into production. In the northwest, Kaiser Gypsum Division of the H. J. Kaiser Co. has recently acquired the perlite mine and processing plant of Dant & Russell, Inc., near Maupin, Ore. The operation is the only one in the country using perlite aggregate as a base for acoustical tile. Reserves of high-grade perlite at this site are estimated as sufficient for 50 years of continuous operation.

[1] *Honestly, dear reader, this is just the way this sentence rolled from the ends of my fingers onto the typewriter. No pun was intended, and only later did I recognize the need for protecting myself by inserting the parenthetical clause above.*

PHOSPHATES—In the Florida field, the year has seen the construction of rather large scale manufacturing facilities for triple superphosphate: Armour & Co. at Bartow, and U. S. Phosphoric Products at East Tampa have increased production facilities for the triple superphosphate; the Davidson Chemical Corp. started construction in July on a new plant for production of triple superphosphate; and International Minerals and Chemical Corp. near Mulberry and Virginia-Carolina Chemical Corp. at Nichols have new triple superphosphate plants nearing completion. At these two latter plants, facilities are being provided for uranium recovery. An impending development worth watching is the production of nitrogen phosphate fertilizers—a compounding process which will yield a more complete fertilizer. Theoretically feasible, it has proved difficult to handle, physically. With encouragement from DMPA, it is reported that a few companies will shortly be in pilot plant production. The occurrence of huge quantities of wavellite, and to a lesser extent pseudowavellite, in the Florida land-pebble phosphate field, was demonstrated during the past year. The material is a widespread zone immediately above the commercial calcium phosphate deposits in the Bone Valley formation of Pliocene age. This discovery offers a possible source of aluminum, although metallurgical processes for separating and recovering the alumina and the phosphate remain to be developed.

In the western phosphate fields, the Westvaco Division of Food Machinery and Chemical Corp. has continued to expand the elemental phosphorus program first undertaken in 1949. It is expected that Westvaco will shortly complete its fourth electric furnace, bringing its elemental phosphorus capacity to 37,000 tons per year at the Pocatello, Idaho, plant. Victor Chemical Works is completing this year the second (the first was finished only last year) of two furnaces at Silver Bow, Mont. for elemental phosphorus. Monsanto Chemical Co. is now completing at Soda Springs, Idaho, what is reported to be the largest elemental phosphorus furnace ever erected.



Quarry in high grade lens of rare earth ore at Mountain Pass mine of Molybdenum Corp. of America, Mountain Pass, Calif. Pit is on west slope.

Stauffer Chemical Co. and Garfield Chemical and Manufacturing Co. are jointly setting up a new phosphate fertilizer plant at Salt Lake City. The wet process to be used will utilize sulphuric acid from Garfield's new refinery-gas recovery-plant and phosphate rock from Stauffer's Idaho and Wyoming deposits. Annual capacity of 60,000 tons of treble super-phosphate is planned. By-product recovery of uranium and vanadium is expected.

POTASH—With the advent of two new producing companies, the Duval Sulphur and Potash Co. and the Southwest Potash Corp., the number of companies operating in the Carlsbad, N. Mex., area totals five. The three older companies have been increasing production and enlarging and improving plant and mining facilities during the year. Freeport Sulphur Co. is continuing exploration in Eddy and Lea Counties, N. Mex., where an extensive potash deposit has been found.

There have been important developments, likewise, in Canada. Saskatchewan's potash deposits, discovered during deep drilling for petroleum are now being investigated by two companies. Western Potash Corp. at Vera has been experimenting with a method of recovering potash by dissolving it in brine and pumping it to the surface. The company has recently announced the letting of a contract to sink a 3500-ft shaft to the deposit on its property, and has also stated that the continuity of the deposit has been proved over a distance of 12½ mi. The Potash Corp. of America has been granted prospecting rights on 175,000 acres of land to the southeast of Saskatoon and will be drilling several wells to test the potash deposits in this area. The granting of pre-prospecting rights over a large area has been recently adopted by the Saskatchewan Government as a means to encourage the development of the potash deposits. It enables a company to make a general investigation of a large tract of land during a stated period and then to select a smaller area for detailed investigation under an exploration permit.

SAND—High-purity silica materials in the form of sand, sandstone and quartzite continued to be in great demand with production at new peaks. Sales of glass-ware products, refractory silica-brick, ceramic glazes, ferrosilicon and refractory sands for molding, held up throughout 1952. A new and unusual use for silica sand was developed during the past year under the trade name of Hydro Frax.

Beginning of the Molybdenum Corp.'s open-cut operation on Sulphide Queen Hill, principal bastnaesite ore body. Barren looking ground is actually high grade ore.

View north of camp and mill at Mountain Pass. Mill treats rare earth ore from nearby Mountain Pass deposit. Old Sulphide Queen gold mine at upper left.

Standard Silica Co., Ottawa, Ill., is currently producing a uniformly-graded sand which has been successfully used in the Mid-continent field to increase flow from depleted oil-bearing horizons. The sand is pumped into wells at 5000 to 8000 lb per sq in., jellied gasoline being used as a carrier. The sand penetrates into the oil-bearing horizon, and aids in opening up fractures and otherwise increasing the size of the pore spaces. This makes possible the salvage of otherwise undiscoverable oil. The U. S. Navy is using significant quantities of sandblast sand in "demothballing" operations on ships in their West Coast yards. This has created a heavy demand for certain types of silica materials in the Pacific Northwest. Suitable raw material is not common in this area and much exploration has resulted. The new flotation plant of the Del Monte Sand Co. (California) commenced operation at the beginning of the year. Using a two stage flotation process, a good quality quartz sand, containing 0.025 pct Fe_2O_3 and 0.5 pct Al_2O_3, and a high alumina concentrate assaying 19 pct Al_2O_3 and 0.10 pct Fe_2O_3 are being produced. Owens-Illinois Glass Co. and Gladding, McBean and Co. are reported to be undertaking tests of the Ione, Calif., sands, with the objective of obtaining a refractory grade clay as by-product from the sand beneficiation. One of the significant developments in the sand industry, which has been going on for a number of years, but which now indicates a clear trend, is the introduction of rod mills for producing specification sand to meet increasingly rigid government and industrial requirements. Rod mills have also been introduced into a number of plants where the natural sand contained an excessive amount of pea gravel which could be economically processed into sand.

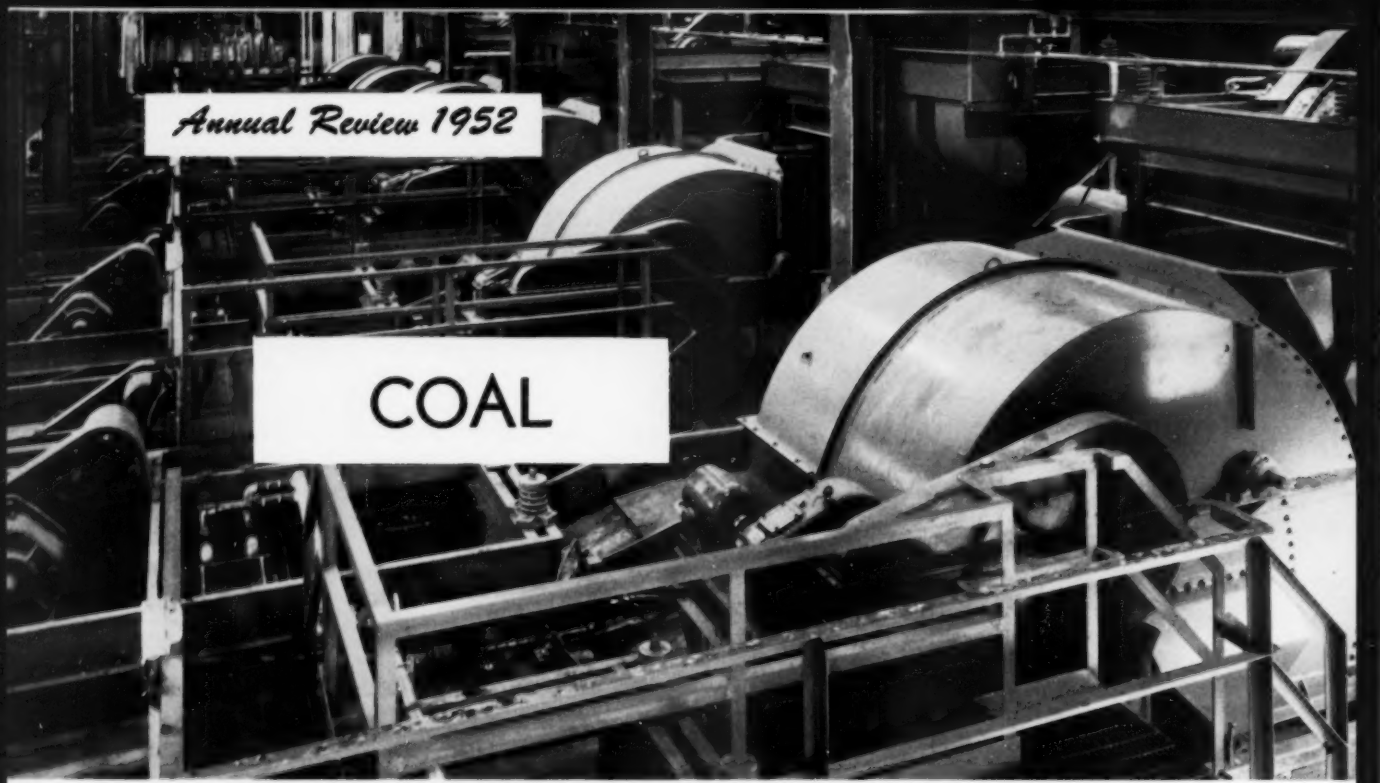
SLAG—Although the steel strike cut sharply into slag production in 1952, sales of slag end-products continued at the same high rate enjoyed the previous year. Production for structural light-weight aggregates increased and slag use as a soil conditioner became more widespread. The National Slag Association in cooperation with the National Board of Fire Underwriters, sponsored tests in 1952 designed to determine the fire-resistive properties of expanded slag aggregate as used in the manufacture of concrete masonry units. As a result of the investigation, Underwriters' Laboratories, Inc., recommended that concrete masonry units made of such materials be included in the existing Standards, thus marking a significant milestone in slag industry.

TALC—Talc continued in good demand and adequate supply for most of the year. Sierra Talc and Clay Co. started production, at about 1000 tons per month of largely steatite grade, from its recently developed deposits near Ennis, Mont. The material is shipped to Grand Island, Neb., where the company put into operation in October a new plant for milling and blending. The trend in demand is toward more and more finely ground material, much of it must now be below 12 microns. In eastern talc areas this is generally accomplished by fluid energy mills; at the Grand Island plant, high speed hammer mills are employed. The Tri-State Minerals Co. (a subsidiary of Southern California Minerals Co.) has opened a deposit near Dillon, Mont., producing largely cosmetic grade talc. Block steatite talc of strategic grade is now all imported. The search for domestic reserves continues.

WATER—To the extent that water is used for industrial purposes it certainly deserves to be included with the industrial minerals—perhaps indeed it is the most basic and the most important of all of our industrial raw materials. Time was when we assumed unlimited abundance of acceptable industrial water supply as casually as some still accept unlimited supply of pure air. But no longer! Industrial water supply in sufficient quantity and of acceptable specifications has already become a matter of major concern in many parts of the United States, and in foreign countries as well. Disposal of industrially used water is likewise a problem for the mining industry, which all too few have yet recognized. At the Regional Fall meeting of the Industrial Minerals Division in Chicago, celebrating the "Centennial of Engineering", a major symposium was devoted to Industrial Ground Water. There should be more symposia, and more research, and more concern on this vital matter.

ZIRCON—There is reported to be a considerable by-product production of zircon from Florida beach sand operations, which at present exceeds demands for this metal with a future. Who will be first to take advantage of this situation?

This review cannot be concluded without acknowledging indebtedness to AIME colleagues in this country and in Canada, in government bureaus, in industrial organizations, in university halls, and elsewhere, who have generously contributed the bulk of the information for this article. Because of their number, they cannot be named individually. It must suffice that I herewith express my sincere thanks to each and all.



Six wheel-type Davis Heavy Media Precision Processors washing coal at the Vesta Washery of the Jones & Laughlin Steel Corp.

Accent is on mechanization, more preparation plants— Competition from other fuels remains biggest problem.

by D. R. Mitchell, A. L. Barrett, and J. H. Kelley

COMMERCIAL coal operators took a severe jolt from John L. Lewis, strongly assisted by President Truman, when the UMWA won a $1.90 a day pay boost during the Fall of 1952. Prior to this pay boost coal was already in a serious competitive situation in certain consuming areas. This pay boost increased the cost of coal to the consumer from 20 to 50¢ a ton, and made it impossible for coal to compete with oil and gas in certain markets and areas.

As a result sales decreased and production dropped. Two work stoppages interfered with output but the amount still exceeded the demand. The year ended with over 80 million tons of coal above ground, a near record. Bituminous mines produced approximately 474 million tons in 1952 as compared to 534 million tons in 1951.

The year ended with King Coal wrestling with the same problems as confronted him at the close of 1951—how to regain markets lost to competitive fuels and how to gain new markets.

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Under present cost conditions it can be expected that coal will lose further ground to competing fuels, particularly in the household, railroad, and general industrial consuming markets. Two phases of the coal consuming industry are increasing—carbonization and public utility. However, increases in these industries are not enough to counter-balance losses to other consumer groups so that a further overall gradual loss of markets is expected in the immediate future.

Two Growing Markets

The large expansion in electric utility plants and in atomic energy plants in or adjacent to coal producing areas has created a demand for increased amounts of coal. In areas away from the coal regions the competitive situation is increasingly favorable for oil and gas. This is shown in the table for the year 1950. Increased costs of coal since then place coal at a decided disadvantage at many places along the entire Atlantic Coast.

Considerable effort is being made to further develop a Coal Chemicals industry. The Carbide and Carbon Chemicals Co. and the Pittsburgh Consolidation Coal Co. during the year announced proposals for expanding the use of coal for the production of

chemicals. These proposals, based on the results of years of research and the expenditure of much money, appear to have considerable merit.

Coal consuming capacity of coke ovens continued to increase. The year 1952 saw the greatest number of new ovens placed in operation for any one year except 1943. Nine hundred ovens were placed in operation having a capacity of 5 million tons. An additional 1300 ovens are under construction and due for completion in 1953. These 1300 ovens will have an annual coal capacity of 7 million tons. In addition, proposals for additional ovens are being formulated. All of this leads to a continuing and satisfactory increase in demand for metallurgical grade coals. Continued expansion in this phase of the coal mining industry can be expected during the next few years.

Other than these efforts to expand coal markets, the best chance for retention of existing markets seems to be in further mechanization of production means to lower costs.

Table I. Average Cost of Fuel to Electric Utilities, By Geographic Areas, in 1950. Source: Edison Electric Institute

	Average Cost in Cents per Million Btu		
	Coal[a]	Oil[b]	Gas[c]
All United States	26.9	31.8	12.1
New England	36.0	32.9	—
Middle Atlantic	27.4	32.3	26.0
East North Central	26.4	59.0	14.3
West North Central	29.1	51.8	15.0
South Atlantic	26.5	31.2	15.2
East South Central	21.7	43.0	13.8
West South Central	18.7	25.0	7.5
Mountain	22.6	42.8	15.7
Pacific	—	21.5	19.6

[a] Bituminous coal, anthracite, lignite, coke.
[b] Fuel oil, crude oil, tar, gasoline.
[c] Natural, manufactured and waste gas.

Mechanized Mining

The acceptance of continuous-type mining and loading machines by the coal and other soft-mineral producing industries is now undisputed. The year 1952 saw the leading manufacturers of mining equipment, working in cooperation with coal mining companies, trying to perfect mineral flow continuity from the discharge point of the face machine to the tipple. These firms devoted extensive programs to the improvement of various types and methods of mineral extraction, transportation, and exploration.

In both short-wall and longwall mining systems, considerable competition between the exponents of the continuous concept and those of the intermittent concept of mineral flow, continued unabated. The former group represented by manufacturers of conveyors, made strenuous efforts to bridge the gap between face loading and secondary haulage. The latter group who are represented by manufacturers of mine cars, locomotives, and shuttle cars, have maintained the superior advantages of surge capacity and have developed improved equipment for the automatic operation of transfer points.

Lower mining costs have been the aim of all parties concerned. On account of the high labor cost of the coal mining industry, increased output per mine worker is the only path open to the mine operator for lowering costs. Much has been accomplished; much remains to be done. Progress has been great. At some underground mines with favorable conditions, the output per worker is approaching that of the strip coal miner.

Many ideas for continuous gathering behind the continuous-type machines materialized during 1952. The first units of the extensible belt conveyor were placed in operation in coal mines. It is a 24 in. wide conveyor with a mobile head unit and a highly maneuverable tail unit which extends the conveyor from 35 to 600 ft continuously, 50 ft at a time. Additional 100-ft belt sections can be attached in 5 min. The intermediate supports are single flexible idlers mounted on lightweight frames each standing independently on the ground.

Another manufacturer has marketed trains of conveyors consisting of a discharge unit, a receiving unit, and up to 20 or more intermediate units. The intermediate units are 15 ft long sections of 24-in. belt, each having a self contained tramming motor and belt motor.

1952 marked several attempts in the United States to apply the continuous mining concept to longwall mining, which has great world-wide interest. This trend grew from the good results obtained with the German planer in post World War II years. Where conditions are favorable, this equipment gives excellent production in longwall mining.

There are, at least ten continuous longwall machines on the market, all of which are of European manufacture. The operating technique of these machines is to slice the length of the long face, discharging onto a gathering conveyor. A snaking chain conveyor for this use had considerable success in 1952. One American manufacturer has developed an extensible hydraulic shaking conveyor of 500 ft maximum length for longwall mining.

The problem of mine roof support along with that of ventilation, has also had its effect in short-wall mining. Roof bolting continues to grow and is now standard practice at many mines. More complete extraction has been made possible by high speed mining and roof bolting.

The concept of remote controlled auger mining, along the high wall of strip pits, having made gigantic strides in recent years, has culminated in the design, construction, and operation during 1952 of a boring-type machine which greatly improves the status of maximum mining depth and directional control. (See "Coal by Remote Control" page 49, January MINING ENGINEERING) This machine is equipped with a sensing device to indicate position with respect to the coal seam. At least three different machines of this type are in development stages.

Progress during 1952 in the field of the conventional single auger machine consisted of these improvements:

1) Ability to mine at increased distances improved.
2) Speed of mining increased.
3) Control of the consistency of direction improved.
4) Minimum size and erectibility of machine and component parts improved.

The depth of auger holes at present is closely related to directional control, since the bending of the auger in the hole greatly adds to frictional resistance to rotation. By using a special pilot auger and longer (25 to 35-ft auger sections, one manufacturer has developed a machine which is able to reach a depth of 200 ft. Most other manufacturers have striven to drill straight holes for greater distances without resorting to the long auger sections, which have great disadvantages with regard to portability

Continuous flow from mine face to surface—LEFT—Receiving section of the Molveyor into which the Jeffrey Colmol delivers coal direct from mine face. RIGHT: Coupled Molveyor sections at an intermediate point on the way back to belt conveyor.

of equipment for underground use and mobility for high-wall use.

For underground use it is imperative that the size of auger sections plus the machine length be less than the entry or room width which is often as little as 9 ft. The year 1952 marked the employment of such underground auger machines manufactured by at least three manufacturers.

A development which may prove to be revolutionary in the coal mining industry is a new method for hardening the tips of cutting, mining, and drilling bits. The supplanting of blasting methods by other methods for breaking coal and soft minerals has put greater burdens upon the manufacturers of bits. Tungsten carbide inserts have experienced increased application but their use in mining is not entirely satisfactory due to the ease with which the inserts are broken from the bit. The new development is a form of case hardening of the bits by the deposition of hard material flakes on the surface of the bits. If mining bits coated in this fashion pass the test of mining, they will create a new era in mechanical breaking of coal and other soft minerals.

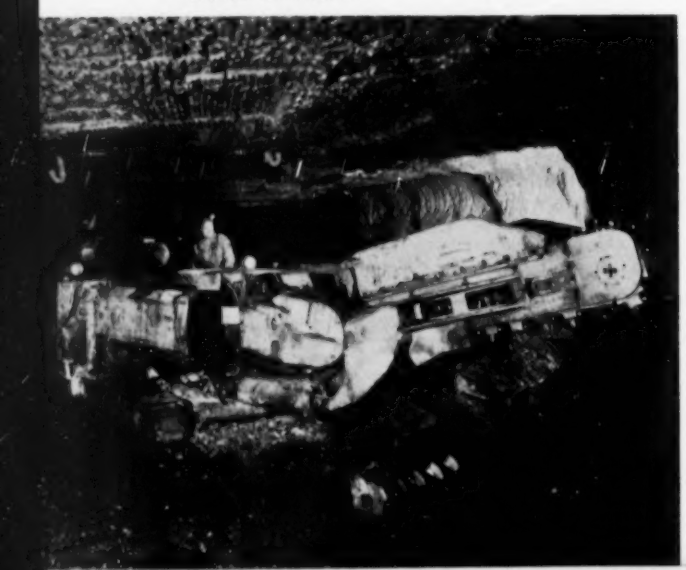
One manufacturer has brought out a line of mining machines which have a minimum height of 26 in. These are for use in low seam coal mines and include a walking continuous-type mining machine of the rotary drum type, a high capacity arm-type loading machine, and a shuttle car on which the operator must lie down.

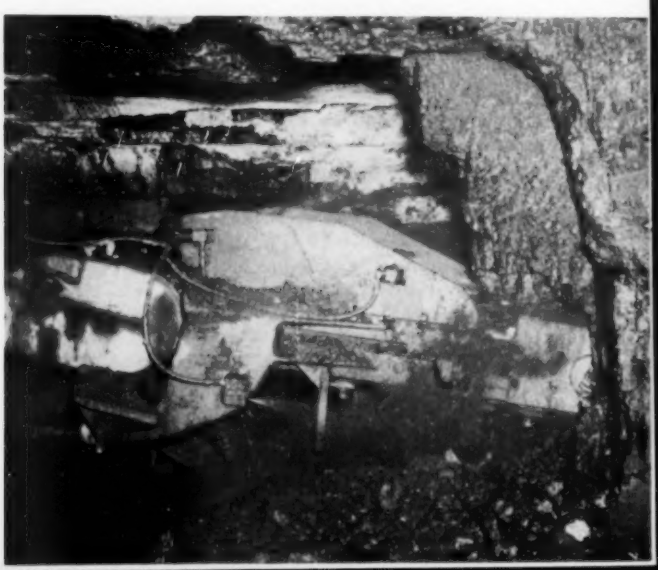
The year 1952 marked also improvements in open-pit mining equipment. Trucks are now used with capacities as high as 50 tons. Stripping shovels have been made more powerful instead of larger. One manufacturer has marketed a new larger blast-hole drill which sinks a 6¾-in. hole faster than was previously possible.

In general, with the nearly universal application of preparation plants to mines, there has been less and less attention paid to more costly face preparation. Also due to the realization by coal users that high grade coals must be conserved, complete extraction has been growing in favor and frequently is found to be the most economical method of mining, particularly with the use of more powerful, automatic, and less selective mining equipment.

Electric power requirements have become so concentrated in the sections that smaller rectifier units —particularly selenium rectifiers which have a low maintenance factor—have become popular. These

LEFT—Joy Continuous Miner in operation driving a room. RIGHT—Closeup of cutters in action. Machine is built in high-vein and low-vein models.





Discharge from Molveyor to belt conveyor carrying coal out of mine.

package units are portable and can be moved, whether underground or on the surface, as the face advances. The year 1952 marked a continuation of the trend toward ac power and high voltages where State Mine Laws permit. Safety with regard to electric power was furthered by the introduction of inverted trolley wires in some mines.

Increased Preparation

Despite the drop in overall production, preparation activity was at an extremely high level throughout the year. Several large new plants were under construction and a number of old plants were being modernized. Much of this activity was at captive mines of the steel or electric utility industry.

The increased demand of the steel industry for high-quality coking coals from areas near to the consuming plants has resulted in the mining of inferior coals since premium coals requiring no preparation are rapidly being depleted. This fact and increased mine mechanization has resulted in the need for new and additional washing facilities.

Dense medium processes made large gains in 1952. Installations of processes using magnetite as a medium were at an all time high. Wheel type units continue to be the most popular, with 10 plants using wheel type washers being under construction in the United States and Europe during 1952. Because of the low headroom and flexibility of this type unit in flow arrangements, it has been found to be particularly suitable for preparation plant modernization planning. Other types in use or in new plant construction plans include revolving drums, screw types, cones, and tank types. At least eight different types of units are now available in the United States.

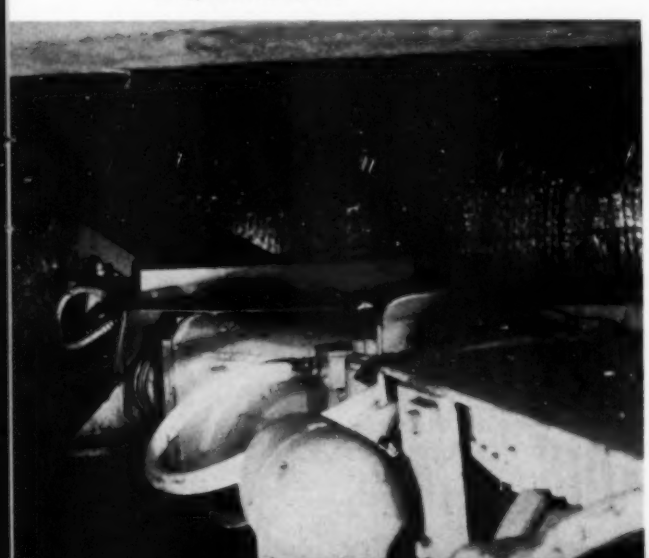
Cyclones continue to receive a lot of attention as partial thickeners and as classifiers. The first installation involving desliming ahead of froth flotation was placed in operation during the year. Four 14-in. cyclones deslime 1200 gpm of slurry at 325 mesh at the Alabama washery where installed. This installation has increased recoveries and improved the grade of product in the froth flotation section of the plant. Cyclones are being experimented with as cleaning devices. No commercial installations have been made.

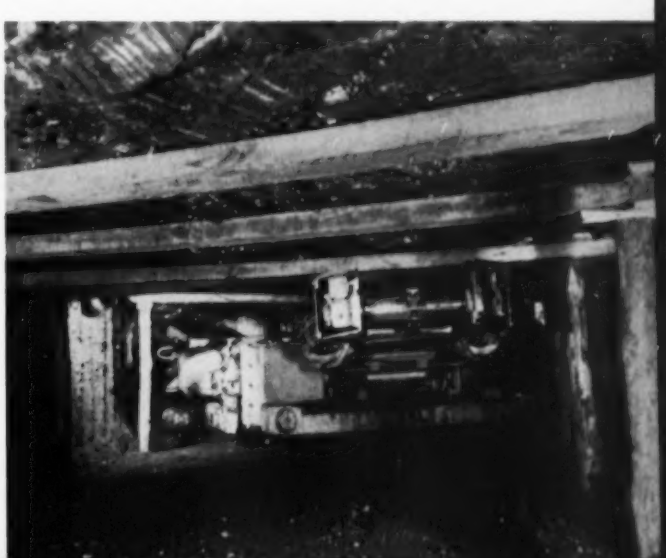
Small coal screening received a lot of attention. Three manufacturers now offer heating units to keep the wires warm and thereby prevent blinding with damp coal. Some experimentation is being done with these units.

A new thermal updraft type coal dryer called the Pulso shows promise. Heat transfer for moisture evaporation is accomplished by bringing the heated gases into direct contact with the coal to be dried.

Considerable attention is being given to improving cleaning circuits. With Baum jig plants this has taken the form of making a middling, crushing, and re-circulation or reducing jig feed size. Dense medium circuits have been greatly simplified and appear to be a great improvement over the traditional circuits. At the Saginaw plant of the Saginaw Dock and Terminal Co., near St. Clairsville, Ohio, the thickener, densifier, and one magnetic separator has been eliminated, giving a very simple magnetite cleaning circuit. Such changes have been made possible by new and improved design of screens and magnetic separators.

LEFT—View from operator's position looking toward cutting head in action. RIGHT—Discharge end of Continuous Miner feeds conveyor or shuttle cars.





Health and Safety in the Mineral Industry

Foreman remains key man in any safety program, as men attracted to the industry must be trained in safety thinking. Diesel engines underground aid safety and widespread use of roof bolting is reflected in reduction of roof-fall fatalities.

by S. H. Ash

THE several branches of the mineral industry are finding it increasingly difficult to obtain and hold a staff of high-caliber workmen and supervisors because of other private industry and government demand for skilled personnel. Advertisements in papers in mining localities from coast to coast seek workmen. Many persons attracted to the mining industry will have to be trained to become safe, efficient workmen. For this reason, if for no other, it is mandatory that the mining industry maintain a first-class staff of supervisors to compete with other private industries and continue progress in obtaining health and safety. The key man in any safety program is the foreman. He must be trained and possess a firm conviction that his position is to provide security, not alone for those under his charge but for himself and his family. Management can well afford to review the status of retirement provisions that inevitably confront their supervisors.

Health

Health of mine workers has more to do with safety and efficiency than is commonly realized. The principal health hazard in the mineral industry continues to be primarily concerned with the abatement and control of dust from drilling, blasting, transportation, and milling. The introduction of Diesel engines underground can be and is a means of providing greater safety by reducing fire hazards and eliminating electrocution hazards. Ample ventilation and suitable exhaust-gas conditioners are the principal means for removing the hazard to health from noxious gases created by Diesels. Although the amount of toxic gases in Diesel-engine exhausts is known to be small, the limited volume of ventilating air circulating in many underground workings and the very small concentration of toxic gases that can be breathed without injurious effect make small toxic-gas production a matter of major importance. All Diesel engines are by no means alike in this respect, and those engines that produce the least volume of toxic gases for the same horsepower should be used in underground workings.

Bureau of Mines records on 61 noncoal mines now using Diesel equipment and Bureau records on 33 heavy-construction jobs where Diesel equipment was or is being used in tunnel work reveal no serious hazard where enough ventilation is provided. Diesel equipment is being used without adverse comment from workmen or State officials. The quantity and quality of ventilation ordered by State regulation are ample and satisfactory.

Experimental and development research by mining and mining machinery companies have always been the means by which progress in mining equipment has been made, and until so-called approved equipment is on the market, government agencies can be of great service to the mining industry by keeping in touch with current practice and trying to make it safer. Because new machines and methods are being introduced continually, what is considered good, sound practice this year may not be acceptable next year; every change in practice and development brings a change in the environment of those who work in mines.

Roof Bolting

The conviction that roof bolting would reflect directly on roof-fall accident records is becoming a reality. While the Bureau of Mines break-down on accident statistics is not available for the years 1950, 1951, and 1952 (when the wide use of roof bolts was introduced), the overall trend of roof-fall fatality rates in bituminous-coal mines is progressively downward, as shown in the following table:

Year	Fatal Roof-Fall Accidents	Fatal Roof-Fall Accidents per Million Tons Mined Underground
Average of 5 years (1942-47)	501	1.21
1948	432	.94
1949	252	.78
*1950	309	.79
*1951	298	.72
*Jan.-Oct. 1952	202	.70

* Estimated.

The State of West Virginia, which had 170 fully mechanized coal mines using bolting on January 1, 1952, reported as follows:

"By computation, the average rate of production per fatality for the 7-year period preceding 1949 is 995,807. For 1951, the rate is 1,914,576. This is an improvement of 92.3 percent in 3 years of bolting.

S. H. ASH, is Chief, Safety Branch, Health and Safety Division, U. S. Bureau of Mines, Washington, D. C.

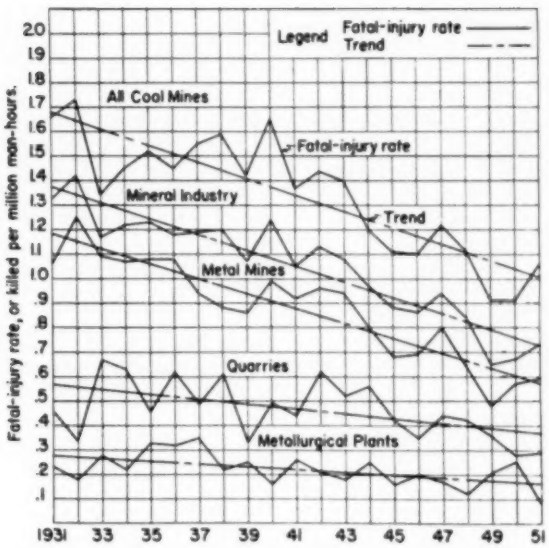


Fig. 1—Fatal-injury rates and trends for mineral industry and its branches, 1931 through 1951. Available statistics indicate the rate for all branches will be lower in 1952 than 1951, and point toward the lowest rate in mining history.

Furthermore, if the previous average rate had continued, there would have been 152 fatalities in 1951 instead of only 79. In 3 years of bolting, by similar estimate, 137 mines have been saved from deaths resulting from falls of roof." (Roof Bolting for Safety, by Joseph Bierer, Dept. of Mines, Charleston, W. Va.)

It is estimated that currently 2¼ million roof bolts are being used per month in 700 mines (600 coal and 100 noncoal) in the United States. Although the systematic use of roof bolts for mine supports originated in metal mines, the application for their use in that field is not nearly as generalized. Nevertheless, the widespread use of roof bolts is developing in several mining districts, notably, iron-ore mining in the Alabama and Lake Superior districts, in Butte, Montana, and in the Coeur d'Alenes. The New York Board of Water Supply is doing an outstanding job of bolting in several of the more recent Delaware Aqueduct projects.

Disasters

Because of the wide publicity given to a mine disaster by the press and radio and the apparent reaction of the public, this is news that has made the mining industry a target for much unjust criticism. As deplorable as disasters are—and they can be prevented—they continue to be from the same sources: explosions, floods, fires, and haulage-equipment failures. The remedies are well-known and have been discussed time and again. Disasters occur because, in most instances, supervision has failed somewhere along the line.

During 1952, three major disasters befell the mining industry—one in a bituminous-coal mine, one in an anthracite mine, and one in (what will be classed) a metal mine. All were probably preventable and would not have occurred if intelligent and complete supervision had been effective. Because such disasters will continue to occur if supervision, especially at small mines, is not drastically improved, these disasters are described briefly.

A gas explosion occurred in a bituminous-coal mine in Pennsylvania on Feb. 2, 1952, causing the death of six men, five of whom were killed outright and one of whom was found alive but died before reaching the surface. Seventy-nine men were in the mine at the time, and sixty-nine men escaped uninjured. Four of these men were directed to the surface through the aircourse by a pumper, and four were rescued and hospitalized. The explosion was confined to a comparatively small area. It originated in a haulage entry near the junction of a borehole entry and a room where an accumulation of methane was ignited by an electric arc from a trolley locomotive. The operating company considered the mine nongassy and consequently provided an inadequate ventilating system by which air that had ventilated abandoned workings and pillar workings was coursed therefrom to active workings and haulage roads on which trolley locomotives are operated. Open-type pumps and locomotives were operated in air returning from abandoned workings and pillar workings where gas was liberated and might accumulate.

In the anthracite region of Pennsylvania, hundreds of small pools are in abandoned bootleg mines. These constitute a menace to future mining, not necessarily because of the volume of water impounded but because of the lack of information available with regard to their size and position. Thousands of these small mines (holes) have been opened from the outcrops and other places where the bed has a shallow cover. The work done in the great majority of these holes is not recorded. The openings to most of these small-mine workings have become obliterated because of caving and other physical changes in the landscape. Where this occurs, it is impossible to obtain data on the extent and direction of the workings. Many of these mines were opened in the outcrops of virgin beds and operated only during dry weather (or as long as a miner could keep the workings free of water with the simple equipment available) and then abandoned. Some of these workings penetrated the anthracite beds sev-

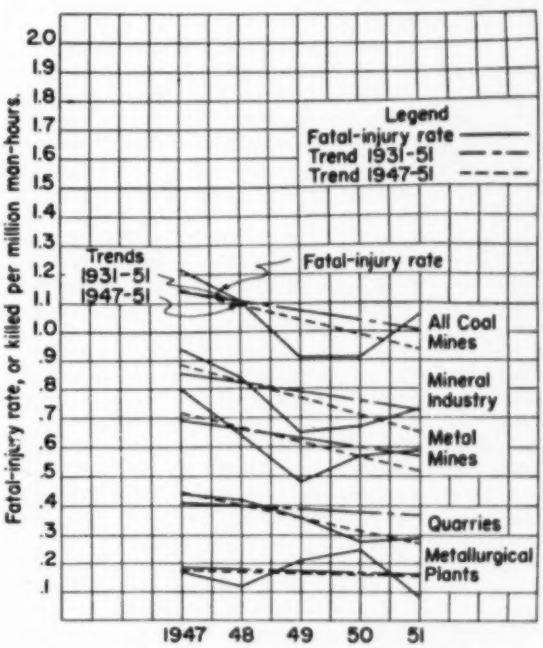


Fig. 2—Fatal-injury rates and trends for mineral industry and branches, 1947 through 1951, with 1931-51 trends for comparison.

eral hundred feet before being flooded. Many of these small mines are not connected to underground workings of other mines and are filled with water, which cannot be pumped to the surface because the portals are closed by cave-ins.

The most recent accident classed as a disaster from flooding occurred on March 27, 1952, when five men drowned in a bootleg mine in the anthracite region of Pennsylvania. Water impounded in this mine was released by a blast and flooded the mine. Seven men were in the mine, but two escaped by running up the slope. The men who escaped were near the bottom of the slope when they heard an explosion and the roar of water. After they reached the surface, one of them descended the slope in a mine car and found the slope filled with water to a point about 215 feet above the bottom.

The mine, approximately 800 feet west of the barrier pillar between the Otto and Lytle mines, is in the Otto area. The Otto mine is abandoned and filled with water to altitude 830 feet; however, the pool is approximately 2,500 feet west of an independent mine and in the Primrose bed. The Lytle mine is abandoned and filled with water to altitude 702 feet.

The opening to the mine is a slope on the southern dip of the Holmes bed and is about 445 feet long on an average dip of 35°. The top of the slope is at altitude 1,019 feet; the bottom, at altitude 767 feet. The inflow of water reached altitude 860 feet. Three hundred feet west of the bottom of the slope, a breast was driven, the face of which is 100 feet above the gangway at altitude 840 feet. A shot was fired in the face of the breast, and water broke in and flooded the mine.

Two pumps having a total capacity of 700 gpm were installed in the slope to unwater the mine, and pumping began late on March 28. The mine was emptied of water late afternoon, March 30, and the last of the five bodies was recovered in the early morning hours of March 31. There are a number of abandoned independent mines in this area, and evidently the water came from one of them.

Experience confirms the fact that inaccurate plans or maps, or their absence, have been the primary cause of the largest number of accidents caused by inundation of water or water-laden materials. Neglect of proper precautions is the second cause, followed by errors in judgment.

It is commonly believed that danger to life and property from mine-fire atmospheres is greatest in coal mines. This is true only to the degree that the explosion hazard is greater in coal mines than in noncoal mines because of the presence of combustible gases. The problem of gas poisoning is greater in noncoal mines because of the more frequent occurrence of poisonous and innocuous gases, oft'times the lack of controlled ventilation, and usually greater difficulty in sealing mine-fire areas. Sulphide minerals present a serious hazard in many metal-mine fires when sulphur dioxide is formed or are a source of dust that is highly explosive.

Although methane is likely to occur in any coal mine, the metal mines of the world contain, by far, a greater variety of gases than do the coal mines. Often, the gases in metal mines are as dangerous as the gases likely to be found in coal mines, and sometimes they are even more deadly.

A methane explosion in a metal mine in Michigan killed five men on October 30, 1952. A sixth man working in a surface building suffered only a bruised right knee and several minutes' loss of consciousness. The explosive mixture of gas was ignited by a hand-held electric drill operated by one of two men taking rock samples 180 feet below the collar of the shaft. The explosion was confined to the shaft and the area immediately surrounding the collar of the shaft.

An article in The Alpena News of November 1 quoted a Michigan State Representative in describing a gas explosion in the shaft of this mine in 1935 that occurred when a worker tossed a lighted match into the shaft. No one was killed or injured. The shaft filled to the collar with water when pumping ceased, and local residents relate that it always has been possible to ignite gas by striking a match near the surface of the water.

Before the recent explosion, methane was liberated in this shaft at one or more points, but no gas-detecting or -indicating equipment was available at the mine. Neither the number of places or the rate of liberation of methane was known nor could be determined during recovery operations or the investigation of the disaster.

The explosion was violent. The shock reportedly was felt in Alpena, 12 miles from the mine. Three bodies were found at distances of 142, 268, and 366 feet and in different directions from the shaft. They were badly torn and partly dismembered, and their faces were charred by third-degree burns. Death was instantaneous. The bodies of the two men recovered from the shaft were not mangled. The type of burns and the absence of any marked violence to the bodies of the two men in the shaft, other than head injuries received by them from impact, indicate that they were in the center of the explosion. The explosion undoubtedly increased in violence as it traveled up the shaft. Muzzle blast, resulting when expanding gases found pressure release at the shaft collar or a highly explosive atmosphere near the collar of the shaft (or both), caused the violence and destruction on the surface.

It is concluded that an explosive atmosphere was formed by the liberation of methane in the improperly and inadequately ventilated shaft and that the explosive atmosphere was ignited by arcs or sparks from the electric drill being used by the men on the cage.

Fatal-Injury Rates

Figs. 1 and 2 show the fatal-injury rates for 1931 to 1951. These continue to trend downward since 1949; however, the over-all trend in all branches except anthracite mines, quarries, and metallurgical plants has been static. From available statistics, the fatal-injury rate for 1952 in all branches of the mineral industry will be lower than in 1951, and points toward being the lowest in mining history.

Accidents in mines will be prevented only by the people who work mines. As the organization of safety committees by due process of law has been beneficial, so is it important and necessary to vitalize safety committees, which will provide machinery to bring local management and worker representatives closer together for a cause that will result in joint benefit, will promote safer mining practices through discussions and adoption of constructive methods, and will establish a basis for mutual understanding and confidence.

It is believed that with adequate safety standards as a basis for mining practice, accidents can be reduced through compliance with these standards. An effective way to accomplish this objective is by education and discipline through the functioning of safety meetings and safety-committee activities.

Improvement of safety in the mineral industry lies within the industry itself. It can be accomplished by giving small groups the same attention in safety education, inspection, and enforcement as required of larger groups. It is in the small mines that a major effort must be made.

It is believed by the author that a letter to the president or any high-ranking official of a mining company, calling his attention to a few outstanding unsafe practices that relate to the possibility of a disaster, is worthwhile and gets results. The signature of the governor of a mining State also gets results, and no high-ranking official is too busy to help if he is given the opportunity.

The United States Gypsum Company Mine, Heath, Montana

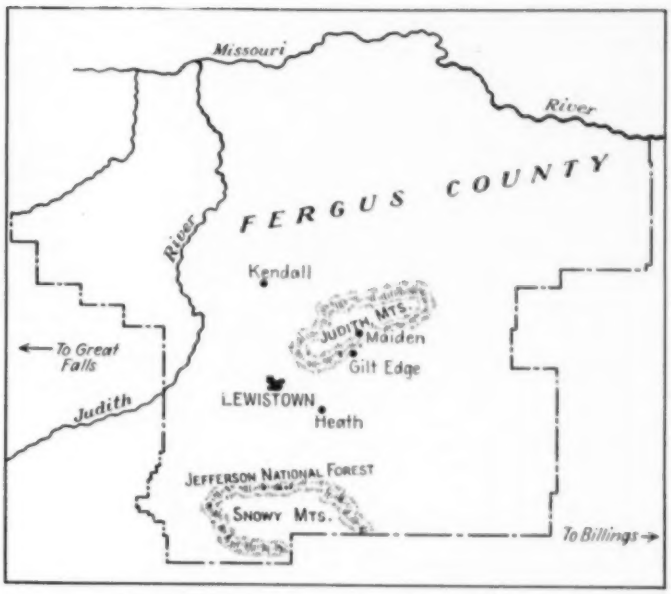


Fig. 1—Gold mine area of Fergus County, Montana.

by Gerald C. Mathis

FERGUS County, Mont., shown in Fig. 1, is known for its once famous gold mines near the old towns of Gilt Edge, Maiden, and Kendall. But at Heath, a small farming community near the foothills of the Snowy Mountains, thousands of tons of gypsum have been mined since 1916. The value of the gold taken from the mines of Fergus County runs into millions of dollars; the value of the products made from the gypsum of the Heath mine is also in the millions. The gypsum mine will continue to produce for many years, while the gold mines are closed today.

The Heath gypsum mine was developed by the Northwest Gypsum Co. in 1916. The products of the small mill built by this company were plaster, agricultural gypsum, and raw gypsum for cement manufacturing. The United States Gypsum Co. prospected the adjacent property in 1916 and 1917 by means of two adits and some exploration drill holes. During World War I, the company abandoned operations at Heath, but again became active in this area in 1928 when it purchased all the property of the Northwest Gypsum Co.

A long range program of expansion was begun with the building of a block plant and the purchase of additional land and mineral rights. A modern wall board plant was built in 1936. When the old wooden mill purchased from the Northwest Gypsum Co. burned in 1937, an all-metal calcining plant located at Blue Rapids, Kansas, was dismantled, moved to Heath, and erected on the site of the mill.

G. C. MATHIS is Mine Superintendent, United States Gypsum Co., Heath, Mont.

Discussion on this paper, TP 3484A, may be sent (2 copies) to AIME before April 30, 1953. Manuscript, Oct. 14, 1952. Los Angeles Meeting, February 1953.

In August 1951 a new mine was opened 3000 ft north of the mill. Rock is conveyed from the mine to the mill by an 18-in. belt conveyor.

The Heath gypsum deposit lies at the base of the Ellis formation of Jurassic Age. The Ellis at Heath lies unconformably on the black fissle shale of the Heath formation of the Big Snowy Group, which is Mississippian in age. The strike of the gypsum bed is N45°E and the dip approximately 3° NW; the regional strike and dip of the area.

The gypsum lies in a series of six layers separated from each other by thin seams of shale. The lower layer is composed of gypsum and shale intermingled and is not of commercial grade. The upper five layers are high in purity, but only the middle four layers are mined on the advance, as the top layer is left for roof support. This top layer is mined on retreating operations at the same time the pillars are robbed. Total thickness of the gypsum layers varies from 12 to 14 ft. Fig. 2 shows the average thickness and arrangement of the layers.

Mining Methods

The mine was originally developed by driving an adit into the gypsum horizon. The Northwest Gypsum Co. mined in the top four layers, the top layer being split, leaving about 12 in. for roof support. A modified room and pillar method was used: entries were 15 ft wide and rooms varied between 20 and 30 ft and were turned on 90° from the entries. Crosscuts between the rooms left pillars from 10 to 20 ft square. The rock was loaded by hand into 1-ton mine cars and pulled to a central gathering point by mules; from the gathering point, mules or horses were used to pull the string of cars to the mill tipple. This method was continued by the United States Gypsum Co. from 1928 to 1937.

The Transactions papers appearing in Mining Engineering during 1953 will subsequently appear in AIME Transactions Vol. 196, and may be permanently referenced to that volume.

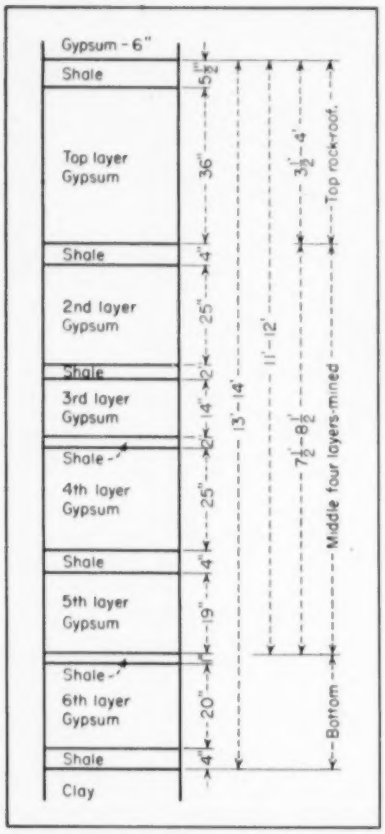


Fig. 2—Stratigraphic column, Heath gypsum deposit.

The addition of the wall board plant in 1936 placed greater demands on the mine, and a 4-ton Whitcombe electric locomotive was purchased in 1937. The locomotive was used to pull the strings of cars from the gathering point to the tipple, and the mules to pull cars to the gathering points.

In October 1942 a general earth movement in the vicinity caused the mine to cave in completely, and to meet demands for rock, a quarry was opened along the gypsum outcrop near the mill site. A stockpile of rock from one of the adits driven in 1916 on the adjoining property was loaded into trucks and hauled to the mill. A new mine to the north and east of the cave-in was laid out on a 45° herring-bone pattern, room and pillar method.

A portable loading slide with an Ingersoll-Rand triple-drum hoist for scraper loading was put into operation in 1943. At the same time a 6-ton Jeffrey electric locomotive was purchased for main line haulage. The Whitcombe locomotive was used to switch the cars behind the scraper-loader. To meet the demand for more production during World War II, another scraper-loader unit and another 6-ton Jeffrey locomotive were purchased and put into operation in 1944. The scraper-loader method was successful but was limited in production and required considerable man power. The scraper-loader is shown in Fig. 3, the Jeffrey locomotive in Fig. 4.

Plans for further modernization of the mine were investigated thoroughly. In 1948 an 18HR-1 Joy Loader and two 60-E Joy shuttle cars were purchased, see Fig. 5. Plans as originally laid out utilized the mine cars for hauling rock to the tipple, but they were altered to permit the shuttle cars to haul direct from the face to the tipple. This required a new haulageway, which was driven with the Joy equipment, first utilized for production in 1949. One scraper-loader and the two Jeffrey locomotives were used as standby equipment in a reserve block along the rail haulage line. The Joy equipment used the 45° herringbone pattern, room and pillar method of the scraper-loaders.

Several factors influenced the decision to change to Joy equipment, flexibility being most important. The mine was nearly exhausted of face rock and robbing of roof and pillars was imminent. The saving in manpower was important also, as good steady workers were hard to find after World War II.

A new mine was opened in August 1951 on the property prospected in 1916. Only the Joy loader and Joy shuttle cars were moved from the old mine for loading and haulage in the new mine. At present there is no standby equipment in the new mine. Thorough inspection and prompt maintenance of the loader and shuttle cars is necessary to keep the equipment operating.

Table I offers a comparison of costs of the above mining methods, showing only those items concerned directly with loading and haulage. All figures are given in percentage of total costs, as labor and material prices have varied over the period covered by the table. The efficiency of the various methods is shown by the tons per total manhour.

Drilling and Blasting

At various times tests have been made to check the efficiency of different rounds in the gypsum at Heath. The best type to date is the Half-V round as shown in Fig. 6. A room round is drilled with 21 holes in vertical rows of 3 holes each. An entry round requires 18 holes. The rib holes of the half V are drilled 6 to 7 ft deep along one rib. The next row of holes is drilled on an angle so that the point of a 10-ft hole is at the point of the corresponding

Fig. 3—Portable loading slide equipped with a 20-hp Ingersoll-Rand triple drum hoist used in the Heath mine from 1943 to 1948.

Fig. 4—A 6-ton Jeffrey electric mine locomotive used for switching and main line haulage in the Heath mine 1943 to 1948.

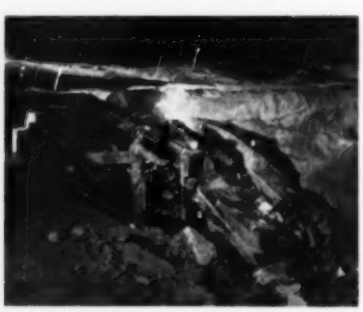


Fig. 5—Joy 18 HR-1 loader and Joy shuttle car in the Shoemaker mine. This equipment was first used by U. S. Gypsum Co. in 1949.

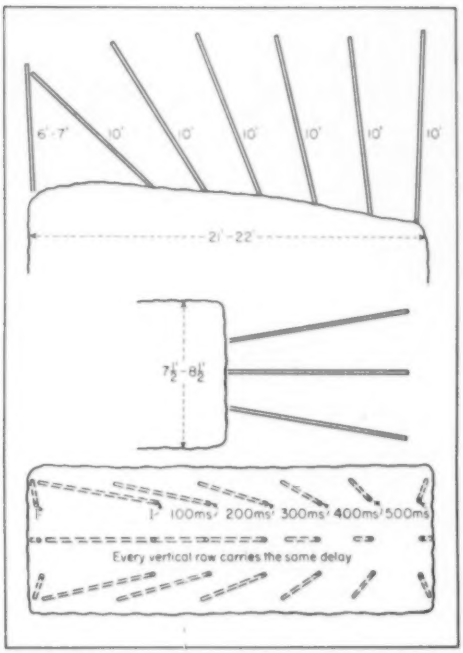


Fig. 6—Blast round, Shoemaker mine. From top to bottom: top view, side view, front view.

6 to 7-ft hole along the rib. Each succeeding row of holes is drilled on an angle leaving approximately 4½ ft of burden on the point of each hole. The last row of holes is along the rib opposite the V side.

The round is drilled with a Jeffrey A-6, electric post-mounted drill. One and one-half inch special twisted conveyor-type auger steel in 4, 6, and 10-ft lengths is used in conjunction with 1⅝-in. No. 37 coal cutter bits. The drill is mounted on a Jeffrey jack-post and has a small block at the top enabling the driller to raise or lower the drill to any desired height. The drill and post are shown in Fig. 7. The drillers each have a wheel-mounted cart which has a grinder mounted on it for sharpening the coal

Fig. 7—A Jeffrey A-6 post-mounted electric drill used for drilling gypsum in the Shoemaker mine.

Fig. 8—Drill cart with grinder mounted used by drillers to move their equipment from face to face.

cutter bits. The cart, Fig. 8, with all the drilling equipment on it, is moved from face to face by hand, or in the case of severe grades by shuttle car. Plans are underway to make the drill carts self-propelled, thus eliminating lost production time on the shuttle cars.

The rounds are blasted with Du Pont Extra D 40 pct, 1⅛x8 in. dynamite. The number of sticks per hole depends on the depth and burden of each hole.

Table I. Direct Cost, Pct, By Years, No Depletion, Development, Or Depreciation Included

	1952 (6 Months)[1] Pct	1950[2] Pct	1948[3] Pct	1944[4] Pct	1940[5] Pct	1936[6] Pct
Loading						
Labor	7.9	7.6	17.5	20.1	35.8	33.6
Repair labor	4.3	3.4	4.5	7.2	1.7	.9
Oiler inspector	1.8	1.6	3.9	2.5	1.9	1.9
Repair material	7.7	6.5	7.8	2.0	.5	3.2
Power	1.9	1.9	1.8	1.3	.7	2.7
Supplies and expense	6.3	4.3	2.9	10.1	3.7	11.9
Total	29.9	25.3	38.4	43.2	44.3	54.2
Haulage						
Labor	5.3	9.9	12.6	10.8	6.1	8.0
Repair labor	1.2	1.2	4.1	6.1	3.5	1.2
Repair material	5.4	3.2	2.3	.9	.4	.2
Supplies and expense	1.5	1.4	2.1	1.5	1.4	3.3
Power	1.8	2.3	1.5	1.3	.4	
Oiler inspector	1.1	1.3				
Total	16.3	19.3	22.6	20.6	11.8	12.7
Total Load and Haul	46.2	44.6	61.2	63.8	56.1	66.9
Tons Per Total Manhr	4.1	3.1	2.1	1.7	1.24	.9

[1] 1952: Joy loading and haulage, no standby equipment, Shoemaker mine.
[2] 1950: Joy loading and haulage, scraper-loader standby.
[3] 1948: Scraper-loader and locomotive haulage, 2 units, last year.
[4] 1944: Scraper-loader and locomotive haulage, 2 units, first year.
[5] 1940: Hand loading, mule tramming, and locomotive main line haulage.
[6] 1936: Hand loading, mule tramming, and haulage.

The round is primed with Du Pont millisecond caps in 100-m sec intervals. The decision to use millisecond caps was made in 1948, resulting in better fragmentation and more even round pull.

Shoemaker Development

Development of the Shoemaker mine was planned well in advance of the initial opening of the mine, which lies 3000 ft north of the mill on the property first prospected by the United States Gypsum Co. in 1916. Diamond drilling had proved that the deposit on the property was large and that it was an extension of the Heath deposit. The 1916 adit was dewatered and retimbered in 1947-48. One of the scraper-loaders and the 4-ton Whitcombe locomotive were moved to the Shoemaker property in 1949 and the work of completing the old adit in a horse-

shoe form was begun. However, work on the adit was slow because of the scarcity of labor, and the other end was not driven to the surface until 1950. This provided both adequate ventilation and two escapeways.

During the years 1947-50 a careful analysis was made of the various types of haulage systems to select the best one to get the rock from the Shoemaker mine to the mill. Although initial investment was high, the analysis favored belt conveying as the most economical and the most suitable to local conditions. The belt installation required a tunnel from the Shoemaker property to the mill. Part of the tunnel was cut 600 ft through the hill between the Shoemaker and Heath mines. This section is timbered with pre-cut creosoted timbers and is 6x6½ ft in the clear. In the Heath mine the tunnel was cut through rooms and pillars an additional 1400 ft to a point near the cave-in of 1942. Here a large room was made for a transfer point. From the transfer point the tunnel is timbered for 400 ft to the surface. The conveying system is housed in a corrugated sheet-iron shed from the surface to the mill, a distance of 400 ft. The 600-ft timbered tunnel with the belt conveyor installed is shown in Fig. 9.

A building to house the jaw crusher was built at the portal of the new mine. Across the coulee, 140 ft away, another building was built to house the hammer mill. The two are connected by a conveyor gallery which houses a 24-in. belt.

On August 4, 1951, the last rock was hauled from the Heath mine. The jaw crusher, hammer mill, and magnetic pulley were moved from the mill and reinstalled in the buildings at the Shoemaker mine. The Joy loader was moved on a heavy-duty trailer and the shuttle cars were moved by bulldozer and truck. The rest of the mining equipment was moved by truck. During the installation of the crushing equipment, six rooms were started along one side of the adit for production. A trial run of 24 tons was made August 8, and after minor adjustments, production started August 9 from the Shoemaker mine.

Development of the Shoemaker mine has progressed steadily. Main entries were advanced 1200 ft north and 1200 ft northeast during the first year. A new system of main entries and sub entries was introduced with the opening of the new mine. Main entries are 16 ft wide with a 20-ft pillar between the parallel entries. Sub entries are turned on 60° angles from the main entries and are 18 ft wide and 400 ft long, with 20-ft pillars. Rooms are turned from the sub entries on 60° angles, and are 21 ft wide and 100 ft long with 15-ft pillars. Since panels are laid out as illustrated in Fig. 10, trolley

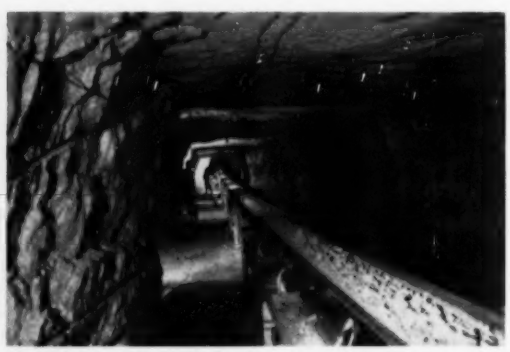


Fig. 9—Part of the 600-ft timbered tunnel with conveyor system installed.

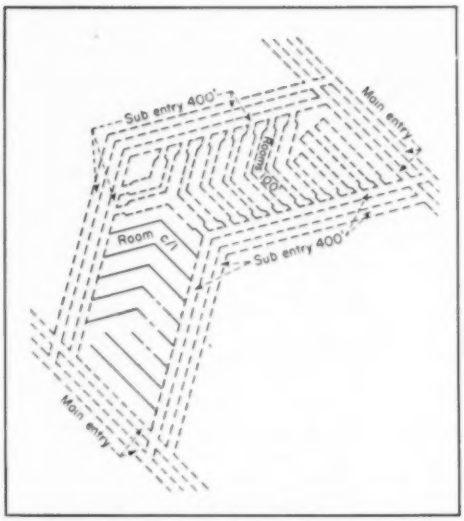


Fig. 10—Cross-cuts entries 120-ft c-l to c-l. No cross cut in rooms. Widths: main entries, 16 ft; sub entries, 18 ft; main and sub entry pillars, 20 ft; rooms, 21 ft; room pillars, 15 ft.

is needed only in the main entries. Shuttle cars have 600-ft cables on reels and can work all the rooms of a set of sub entries from the main entry trolley.

The drill pattern, shooting system, and method of loading and hauling used in the Heath mine were continued in the Shoemaker mine. The shuttle cars haul direct to the portal where the rock is dumped into a Joy elevator for elevating into the jaw crusher.

Rock as it comes from the mine is usually 18 in. or less. Any oversize is broken down with a Thor paving breaker before it is run through the jaw crusher. The jaw crusher, a Butterworth and Lowe, 18x30-in., crushes the rock to —6 in. at the rate of 50 tons per hr. A 24-in., 5-ply, nylon cord Goodyear belt conveys the rock from the jaw crusher across a magnetic pulley to the hammer mill. This mill, a Jeffrey swing-hammer type, crushes rock to —2 in. at the rate of 70 to 80 tons per hr. A small 3-ton surge bin under the hammer mill feeds onto a Syntron feeder which can be regulated to feed the conveying system at any rate up to 100 tons per hr.

The conveyor belt, an 18-in. wide, 5-ply, nylon cord, mildew-resistant Goodyear, is in two flights. The first flight is 2000 ft long with a net rise of 28 ft. The belt is driven by a 20-hp, 440-v electric motor connected to a Falk gear reducer. From the transfer point there is a second flight which is 800 ft long with a net rise of 40 ft. This portion of the belt is driven by a 15-hp, 440-v electric motor connected to a Falk gear reducer. The carrier frame was fabricated by Haak Engineering, Denver, Colo. and is equipped with Rex-Stearns idlers. Self-aligning idlers are placed every 100 ft on the top side and every 250 ft on the return side. The entire system from the small belt over the storage bin at the mill to the jaw crusher at the mine is interlocked to protect all parts.

Acknowledgments

The author wishes to acknowledge the assistance given him by all members of the Heath plant and especially to William Freund, Mine Foreman, and O. M. Newsum, Mill Foreman.

A Method for Concentration of North Carolina Spodumene Ores

by Mason K. Banks, William T. McDaniel, and Philip N. Sales

A process has been developed which produces spodumene concentrates assaying 6.0 pct Li_2O and 0.45 pct Fe_2O_3, with 70 to 75 pct recovery of spodumene. Two flotation separations are required: the simultaneous removal of mica, feldspar, and quartz as a froth product using a cationic collector, and the subsequent removal of iron-bearing minerals as a froth product while spodumene is depressed as a tailing.

SINCE the close of World War II there have been numerous developments resulting in the increased use of lithium by industry. Notable among these has been the development of an industrial lubricant, based on lithium stearate, which is fluid at low temperatures, stable at high temperature, and insoluble in water. A new bleaching agent, lithium hypochlorite, has also been developed recently.[1] Other well-known uses are listed below:

1—Lithium oxide in ceramics reduces firing time, lowers melting temperatures, lowers thermal expansion, raises refractive index, and improves chemical resistivity. 2—Lithium carbonate and lithium strontium nitrate are used in pyrotechnics for their brilliant red color.[2] 3—Lithium chlorides and fluorides are used as fluxes for welding aluminum and magnesium.[2] 4—The affinity of lithium for nitrogen is the basis for a process used in purifying helium.[3] 5—Lithium chlorides and bromides are used in air conditioning for their powers to absorb organic amines, ammonia, and smoke.[1] 6—Lithium hydride has been used as a source of hydrogen to inflate life rafts and balloons used by the Air Forces and Navy.[1] 7—Lithium metal and lithium hydride are useful in the atomic energy program in connection with the production of the isotopes of hydrogen.[3]

During the 1942–45 period of World War II, Solvay Process Co. operated a flotation plant with a daily capacity of 300 tons of ore for the production of spodumene concentrate near Kings Mountain, North Carolina. The operation was shut down upon reduction of wartime demand for lithium chemicals, and until recently there has been no production from the Carolinas.

In April 1950 an investigation of the problem of spodumene flotation from North Carolina ores was begun at North Carolina State College Minerals Research Laboratory at Asheville, N. C. This laboratory, operating under the combined auspices of North Carolina State College, North Carolina Department of Conservation and Development, and the Tennessee Valley Authority, undertook the spodumene project at the request of Foote Mineral Co. of Philadelphia. The work, involving a period of 15 months of intensive batch and pilot plant investigation, was completed in June 1951 and resulted in development of a process for concentration of spodumene by flotation which has been hereto unrecorded in the literature. A similar approach has been used before on iron, ilmenite, and other minerals, but the literature shows no record of its having been applied to spodumene. Parts of the process are now being used on a commercial scale at the Foote Mineral Co. plant near Kings Mountain, N. C., which has been in production since July 1951. It is the purpose of this paper to describe some of the results of the investigation.

The Orebodies

Spodumene-bearing pegmatites occur in a narrow belt 24.5 miles long and 1.8 miles wide extending southwestward from Lincolnton to Grover, N. C. According to statements judged to be conservative, the tin-spodumene belt of the Carolinas contains an estimated 4,300,000 tons of pegmatite ore averaging 15 pct spodumene. This amounts to "a reserve of at least 650,000 tons of spodumene (more than 20,000 tons of metallic lithium) to a depth of 100 ft."[4] This figure includes only bodies having an average thickness of 35 ft and length of 550 ft. There are hundreds of pegmatites in the belt, many of which are less than 10 ft wide. The largest pegmatite in the area has a maximum thickness of 395 ft and maximum length of 3250 ft.[4]

These larger pegmatites are composed principally

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of albite and microcline feldspars, albite predominating, quartz, spodumene, and muscovite. There are many accessory minerals, but the important ones are cassiterite and beryl, and possibly columbite-tantalite. Approximate composition of ores from the belt which were used in this investigation is shown in Table I.

Table I shows that quartz and muscovite content remain fairly constant in all the ores, while feldspar content increases when spodumene content decreases, and vice versa. This is interesting because feldspar is potentially an important byproduct.

The Spodumene

According to Boyd,[5] the following analysis is typical of the Carolina spodumene:

SiO_2	Al_2O_3	Li_2O	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Ignition Loss
63.84	28.61	7.26	0.19	0.04	Trace	Nil	Nil	0.16

Spectrographic analysis shows the presence of minor amounts of MnO, TiO_2, SnO_2, Ga_2O_3, Na_2O, and K_2O in the spodumene. One sample contained Rb_2O. Petrographic and X-ray studies indicated that these impurities are probably isomorphous replacements in the crystal structure of the spodumene.[6]

The molecular dispersion of the iron within the spodumene crystal has been substantiated by acid-leaching and magnetic separation tests in which the Fe_2O_3 content of spodumene crystals remained from 0.15 to 0.40 pct after magnetic separation and acid leaching.[7]

The iron content of the spodumene crystals is usually reflected in the color of the crystals, the colorless to white variety containing from 0.08 to 0.20 pct Fe_2O_3, the buff or cream variety containing 0.20 to 0.40 pct Fe_2O_3 and the yellow or greenish-yellow variety containing up to 0.65 pct Fe_2O_3. The darker the color the higher the iron content of the spodumene.

The amount of iron dispersed in the spodumene crystals is a significant factor, since it affects the use to which the concentrates may be put. For use in ceramics the spodumene concentrate should contain less than 0.5 pct Fe_2O_3, but for use in extraction of lithia for chemical purposes the presence of iron presents no special problem. None of the Carolina belt samples tested contained spodumene with low enough isomorphous iron content to yield a product with less than 0.2 pct Fe_2O_3. The average iron content of spodumene concentrates prepared from these ores was 0.40 to 0.50 pct.

The Carolina spodumene is somewhat variable in Li_2O content, but apparently averages approximately 7.0 pct or slightly in excess of this figure, although the textbook gives 8.03 pct theoretical Li_2O. Some variation is caused by weathering, for it has been established that Li_2O is lost by leaching when the rock undergoes weathering, just as the Na_2O and K_2O are lost in kaolinization of feldspar.

Review of Concentration Methods

The literature reveals the following methods used for production of spodumene concentrates: 1—The spodumene of the Black Hills of South Dakota was present in such large crystals that it was easily concentrated by selective mining and hand sorting. 2—The Bureau of Mines developed a method by which alpha spodumene was decrepitated at a temperature between 1000° and 1100°C, changing its form to beta spodumene, a soft pulverulent material, which could be recovered from the harder gangue minerals by differential grinding following the decrepitation.[8] 3—Froth flotation of spodumene using anionic collectors, or fatty acids, in an alkaline circuit was worked out by the Bureau of Mines and enlarged upon by Norman and Gieseke.[7] This method was utilized by Solvay Process Co. at Kings Mountain, N. C., during its wartime operation. 4—Froth flotation with sulphonated oils in an acid circuit was also shown to be feasible, as well as a method of producing a feldspar-spodumene mixture by using cationic collectors in an HF circuit.[7] 5—A mill at Keystone, S. D., operated by Lithium Corporation of America has been utilizng the heavy media method, treating 15 tons of $-1\frac{1}{2}$ in. ore per hr and producing a concentrate of 4 to 5 pct Li_2O.[2]

All the above methods have their advantages and disadvantages. The method described on the following pages is presented merely as a different approach and is acknowledged also to have both advantages and disadvantages.

The Flotation Process

The final process developed for spodumene concentration of North Carolina ores revolves around two primary flotation separations: 1—a process whereby mica, feldspar, and quartz are simultaneously removed as a froth product while spodumene and iron-bearing minerals are depressed as a tailing, and 2—the subsequent removal of iron-bearing minerals as a froth product while spodumene is depressed as a tailing. The removal of silicate gangue minerals in Step 1 is accomplished in an alkaline circuit, with a long-chain amine used as collector, and a colloidal depressant, such as starch or dextrine, used as selective depressant for the spodumene and for the iron minerals. The iron minerals are removed in an acid circuit, with sodium resinate used as collector and hydrofluoric acid as controller for prevention of spodumene flotation. Suitable frothers are used in both floats.

Table I. Ores Used in Investigation of Spodumene Flotation

Ore, Lab. No.	Sampled by	Spodumene, Pct	Feldspar, Pct	Quartz, Pct	Mica, Pct	Others, Pct**
808	Laboratory staff	38	30	26	3	2
837-A	Foote Mineral Co.*	36	33	26	3	2
971	Consolidated Feldspar Corp.	23	41	27	5	4
943	Foote Mineral Co.	19	45	25	4	7
969	Foote Mineral Co.	22	42	25	4	6
985	Foote Mineral Co.	13	56	22	4	5

* The Foote samples contained 0.03 to 0.05 pct Sn, or approximately 1.0 lb Sn per ton of ore. These came from the old Solvay quarry about 1 mile SW of Kings Mountain.

** Includes horneblende gneiss and sericite schist particles from wall rock and inclusions, as well as beryl, cassiterite, and numbers of accessory pegmatite minerals present in trace quantities.

The gangue froth product containing mica, feldspar, and quartz may be split into its component parts for recovery of a feldspar byproduct. Since approximately one-third of the feed is generally recoverable as a feldspar concentrate, it was felt that efforts to recover it should be made. The general procedure for feldspar recovery would be to dewater the gangue froth product and then treat it in the conventional manner for feldspar ores, i.e., removal of mica with sulphuric acid and amine, washing by classification, then flotation of other iron-bearing silicates with sulphonated oil or fatty acid collectors, and finally flotation of feldspar from quartz with the conventional hydrofluoric acid-amine process.

Table II. Batch Test Results

Spodumene

Lab. No. 808 Head Sample: 38 pct spodumene, 0.24 pct Fe_2O_3 in spodumene crystals.

Product	Wt, Pct	Pct	Units	Dist.	Fe_2O_3	Al_2O_3	SiO_2	(1) Li_2O	(2) Li_2O
Spodumene conc.	29.4	91	26.8	70.8	0.26			6.55	
Iron froth product	3.2	62	2.0	5.3				4.85	
Mica froth product	4.2	4	0.2	0.5				0.45	
Feldspar froth product	21.0	14	2.9	7.7	0.07		67.0	1.25	
Quartz tailing	29.8	8	2.4	6.3	0.04		93.3	0.75	
Slime and oversize	12.5	29*	3.6*	9.5*					
Total	100.1		37.9	100.1					

Spodumene

Lab. No. 837-A Head sample: 36 pct spodumene, 0.43 pct Fe_2O_3 in spodumene crystals.

Product	Wt, Pct	Pct	Units	Dist.	Fe_2O_3	Al_2O_3	SiO_2	(1) Li_2O	(2) Li_2O
Spodumene conc.	33.8	89	30.1	83.6	0.44			6.50	6.44
Iron froth product	1.9	50	1.0	2.8	8.29			4.05	4.50
Mica froth product	1.5	3	0.1	0.3				0.35	0.52
Feldspar froth product	27.5	8	2.2	6.1	0.09	19.9	68.4	0.70	0.68
Quartz tailing	20.9	1	0.2	0.6	0.02		98.0	0.10	0.11
Slime oversize	14.4	18*	2.4*	6.7*					
Total	100.0		36.0	100.1					

Spodumene

Lab. No. 943 Head sample: 19 pct spodumene.

Product	Wt, Pct	Pct	Units	Dist.	Fe_2O_3	Al_2O_3	SiO_2	(1) Li_2O	(2) Li_2O
Spodumene conc.	14.3	82	11.7	63	0.86			6.10	6.40
Iron froth product	2.6	55	1.4	7				4.35	4.00
Mica froth product	6.0	5	0.3	2				0.50	1.19
Feldspar froth product	37.9	7	2.6	14	0.26	20.6	66.0	0.70	1.40
Quartz tailing	20.1	1	0.2	1	0.14		94.1	0.10	0.36
Slime oversize	19.1	13*	2.4*	13*					
Total	100.0		18.6	100					

Spodumene

Lab. No. 971 Head sample: 23 pct spodumene, 0.47 pct Fe_2O_3 in spodumene crystals.

Product	Wt, Pct	Pct	Units	Dist.	Fe_2O_3	Al_2O_3	SiO_2	(1) Li_2O	(2) Li_2O
Spodumene conc.	22.8	84	19.2	83.5	0.56			6.25	
Iron froth product	1.0	94	0.9	3.9				6.70	
Mica froth product	4.4	1	0.0	0.0				0.10	
Feldspar froth product	36.6	4	1.5	6.5	0.12	20.4	68.1	0.40	
Quartz tailing	20.8	1	0.2	0.9	0.05		96.5	0.10	
Slime and oversize	14.3	8*	1.2*	5.2					
Total	99.9		23.0	100.0					

(1) By using curve showing Li_2O vs percent sinks in acetylene tetrabromide.
(2) By actual chemical analysis.
* Calculated using head sample analysis.
Distribution of spodumene based on percentage of sinks in acetylene tetrabromide.
Li_2O analyses by Foote Mineral Co.

The final process which breaks the ore into its component parts is described generally as follows:

1—Grinding. The ore as received was ground in a batch rod mill at 25 pct solids to pass a 28-mesh screen. The +28 mesh fraction, consisting almost entirely of mica, was removed. The −28 mesh fraction was deslimed by decanting over a 325-mesh screen. Approximately 0.5 lb caustic per ton of feed was used in the mill to keep the pulp dispersed for desliming. The oversize product consisted of approximately 1.0 pct weight of the feed, while slime loss came to 12 to 18 pct weight of the feed. Separations were obtained with feed as coarse as 20 mesh, and the general range of 20 to 28 mesh was satisfactory. The feed should be sized by screening or classification, with oversize returning to the mill in practice. The rod mill is preferred to the ball mill, because it produces a coarser, more granular feed with much closer size distribution. It is believed that ball milling would produce excessive slimes and a long particle size range, both of which have been shown to be undesirable in this process.

2—Rougher Gangue Flotation. The deslimed −28 mesh +325 mesh pulp was placed in a Denver 2000-g laboratory flotation machine and brought to 20 to 25 pct solids. The following reagents, calculated in pounds per ton of dry mill feed, were added: 1.0 lb per ton of lime, 0.5 of dextrine, 0.4 to 0.7 of Armac T, and 0.4 of B-23. The pulp was conditioned for 1 min, then floated for 4 min, with the quartz, feldspar, and mica being simultaneously removed as a froth product. The spodumene and iron-bearing minerals were selectively depressed and removed as a tailing. Most of the froth was removed in 2 min. The float is heavy and fast if sufficient frother is used. The rougher is more selective if little or no frother is used, but requires more collector (Armac T) and an excessive float time. Lime and dextrine are more selective and cheaper than caustic and dextrine, although either may be used. If dextrine is not available, causticized-starch may be used, although dextrine is preferable. An excess of starch or dextrine does not break down the separation, but merely causes an increase in collector required. Approximately 0.5 lb per ton of dextrine or causticized-starch is generally sufficient to depress the spodumene. An excess of caustic or lime can cause complete breakdown of the separation as the amine collector is unstable when the pH is above 11.5.

3—Cleaner Gangue Flotation. The rougher gangue froth was next placed in the cell at 15 to 20 pct solids with 0.5 lb per ton of lime, 0.5 of dextrine, and 0.2 of B-23. It was conditioned 15 sec, then floated 4 min. This is virtually a repetition of the rougher, for the purpose of dropping out fine spodumene particles which were mechanically entrained in the heavy rougher froth. It requires no additional collector. If sufficient frother is used, the cleaner tailing or middling is a high-grade spodumene concentrate and may be combined with the rougher tailing.

4—Iron Mineral Flotation. The combined rougher tailing and cleaner tailing, consisting of a high-grade spodumene concentrate with substantially all the

iron-bearing minerals present, was then washed by decantation, thickened to 65 to 75 pct solids, and conditioned for 10 min with 0.35 lb per ton of HF (100 pct), 2.0 of sodium resinate, and 0.1 of B-24. The pulp was transferred to the cell and floated 4 min at 25 pct solids, with iron-bearing minerals being removed as a froth product, and relatively iron-free spodumene, except for molecularly contained iron discharged as a tailing. The tailing is the finished spodumene concentrate, which may be thickened, filtered, and dried in conventional manner. The sodium resinate collector was chosen over sulphonated oils as iron-mineral collector because it tends to concentrate the spodumene by floating mica and feldspar impurities along with the iron minerals, whereas the sulphonated oils tend to float pure spodumene along with the iron minerals. It is most important to maintain pulp density in the conditioner as high as possible before flotation of iron minerals.

5—Mica Flotation. The cleaner gangue froth was next conditioned for 3 min with 1.0 lb per ton of H_2SO_4, 0.1 of B-23, and 0.05 of Armac T at 35 pct solids. Mica was then removed as a froth product.

6—Feldspar Flotation. The quartz-feldspar tailing from the mica float was washed by decantation, then conditioned 6 min at 50 pct solids with 1.5 lb per ton of HF (100 pct). It was then placed in the cell and diluted to 25 pct solids; 0.05 to 0.20 lb per ton of Armac T and 0.3 of B-23 were added before flotation. Feldspar was removed as a froth product and quartz was discharged as a tailing.

Results on batch testing several ores according to this outlined process are shown in Table II. Fig. 1 is a flowsheet of the process.

Discussion of Table II

Test results on four separate ores are shown in Table II to illustrate the amenability of various ore types and grades to separation by this method. Lithia content is given in two of the test summaries to show the comparison between actual chemical analysis for lithia and lithia content based on distribution of spodumene. It should be observed that lithia minerals must be considered on a dual basis: first, the mineral, which is all the mill operator can recover, and second, the lithia content, which is all-important to industry. Recoverable spodumene crystals in some instances may not contain more than 3.0 to 5.0 pct Li_2O owing to loss by leaching action of weathering, replacement of Li_2O by other molecules, etc. Other points which should be noted in explaining the seeming discrepancies between spodumene content and lithia analysis are: 1—The mica in the pegmatites contains a small amount of Li_2O. This throws any attempt to check spodumene distribution with Li_2O distribution slightly off. 2—The Li_2O content of the spodumene itself is variable. 3—Accuracy of Li_2O analysis is subject to serious error because of its complexity.

For these reasons, results were evaluated in terms of spodumene distribution rather than lithia distribution. Actual lithia analyses were made at intervals for check purposes and these are shown where available.

It will be noted that the iron content of the spodumene concentrates is usually slightly above that of the picked spodumene crystals from a given sample. The iron content of the crystals is part of the molecule and cannot be removed by physical means.

Ores 808 and 837-A were higher grade than average and in fresh, clean condition. No trouble was encountered in making very good lithia grades and recoveries on this type of ore. Feldspar concentrates were also of good quality on these two ores.

Ore 971 was a medium-weathered, high-iron content spodumene ore, but was still definitely amenable to this process, as shown by the results.

Ore 973 was badly weathered and contained considerable kaolinized material and horneblende. This resulted in high-iron feldspar concentrates and high-iron spodumene concentrates. This ore severely tested the process, but spodumene concentrates containing 6.10 pct Li_2O minimum were prepared from it with a recovery of 63 pct. One of the chief conclusions drawn from handling ores like this was that an acceptable grade of concentrate could be made from badly weathered ores, but recovery would suffer. Horneblende was outstanding as the most difficult contaminant to cope with. It consistently reported with the spodumene concentrates when present in the ore, and was not easily separated therefrom. The chief loss of spodumene values occurred in the slimes, and the next highest loss in the feldspar concentrate. The spodumene recoveries shown compare favorably with those obtained in feldspar flotation, with which this type of processing is most closely comparable.

Pretreatment of Weathered Ores

It was found necessary to employ light attrition scrubbing on ore types which were weathered appreciably. Unless alteration products were removed from the mineral particle surfaces, selectivity was rather poor. This condition had been noted previously in application of anionic flotation to these same ores.[7] The principal effect of weathering on this cationic float was to inhibit flotation of stained particles of quartz and increase amine consumption. This substantially lowered the grade of concentrates obtained. It was found that conditioning at 65 to 70 pct solids for 5 to 10 min with 4 to 5 lb per ton of caustic followed by a decantation wash was effective in removing the alteration products on particle surfaces. When the spodumene-gangue separation

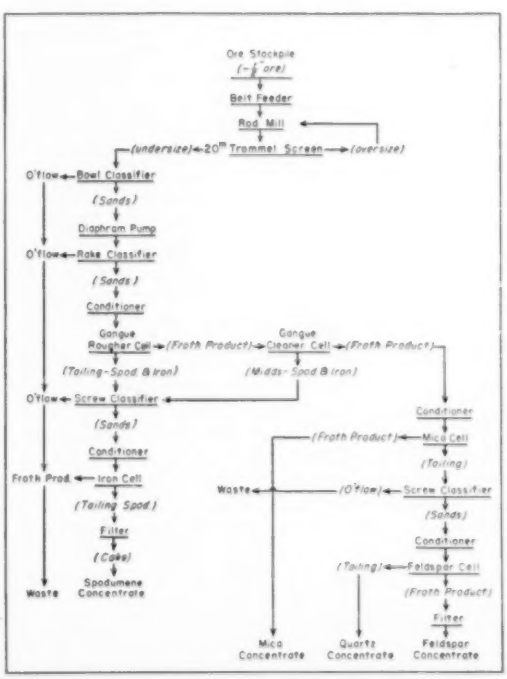

Fig. 1—Proposed spodumene flotation plant flowsheet.

Table III. Results of Batch Tests

Test 1 Dilute grind, 25 pct solids. No scrubbing.

Item	Wt, Pct	Spodumene, Pct	Spodumene, Units	Distribution of Spodumene
Spodumene conc	20.0	71.0	14.3	65
Gangue froth	69.3	8.0	5.3	24
Slime loss	10.7			11
Total	100.0			100

Test 2 Dilute grind, 25 pct solids. Scrubbed 6 min at 75 pct solids with 5.0 lb per ton NaOH. Washed.

Item	Wt, Pct	Spodumene, Pct	Spodumene, Units	Distribution of Spodumene
Spodumene conc	16.1	90.7	14.6	66
Gangue froth	72.9	5.4	3.9	18
Slime loss	11.0			16
Total	100.0			100

Test 3 Thick grind, 60 pct solids with 4.0 lb per ton NaOH in grind.

Item	Wt, Pct	Spodumene, Pct	Spodumene, Units	Distribution of Spodumene
Spodumene conc	20.2	86.3	17.3	79
Gangue froth	66.3	5.0	3.3	15
Slime loss	13.5			6
Total	100.0			100

was performed on weathered ores which had been scrubbed in this manner, selectivity was usually as good as that obtained on fresh, unweathered ore samples.

An alternate method was also found to be effective. This alternate method was to change the grinding pulp density from low to high percent solids, using 4 to 5 lb per ton of caustic in the mill, thereby getting a scrubbing action in the mill. This procedure resulted in improved flotation selectivity, but changed the nature of the mill discharge from a rather coarse, uniformly-sized feed, to a finer feed with a much greater range of size.

Of these two methods of handling weathered ores, the one utilizing dilute grinding conditions and a separate scrubbing step has been shown to be the best procedure, although the alternative use of the mill as a scrubbing device may be used if it becomes expedient to do so.

The following three batch test results, see Table III, indicate the beneficial effect of scrubbing on a weathered ore. In each case shown, treatment of the samples was identical except for grinding and scrubbing conditions as indicated. Feed was Lab. No. 969.

Pilot Plant Tests

Since the method outlined in the preceding pages represented a novel approach to spodumene flotation, it was decided to make pilot plant tests so that the spodumene-gangue and spodumene-iron separations could be studied under continuous operating conditions. Part of the necessary equipment was furnished the laboratory by Foote Mineral Co.

The flowsheet followed was the same as that shown in Fig. 1, except that the gangue froth product was collected as a bulk froth product with no attempt made to separate the mica, feldspar, and quartz. Grinding conditions were set up to utilize the mill as a scrubbing device, i.e., high density grinding with caustic. Feed rate for most of the tests was 300 lb per hr of $-\frac{1}{2}$ in. ore, and a total of 15 tons of ore was used in these tests. Operating time on the test runs varied from 2 to 8 hr. Two ore samples were studied in this manner, Lab. No. 969 containing 22 pct spodumene, and Lab. No. 985 containing 12.5 pct spodumene. Seven complete tests were made on each ore. Variables studied in these 14 continuous pilot plant tests included amount of caustic used in the mill, pH studies in rougher and cleaner gangue floats, conditioning time and cell retention time in the gangue float section, comparison of pine oil, B-23, and cresylic acid as frothers, determination of optimum dextrine and amine amounts required, studies comparing sulphonated oils with soap as iron mineral collector, conditioning time and cell retention time in the iron float section. A short study was also made of the problem of concentration of the small amount of cassiterite which occurs in the spodumene ores. The cassiterite problem is not considered within the scope of this paper, but is mentioned to indicate that the presence of the mineral

Table IV. Results of Pilot Plant Tests

Test 2

Operating Conditions

Feed:—½ in. Lab. No. 969, 22 pct spodumene, 0.89 pct Fe_2O_3, fed at 300 lb per hr. Mill discharge —28 mesh.

Equipment	Reagent	Quantity Reagents, Lb Per Ton	pH	Solids, Pct
Rod mill	NaOH	4.34		65
Rougher cell	NaOH	0.27	10.9	20
	Dextrine	1.15		
	Amine	0.90		
	Pine oil	1.13		
Cleaner cell	Dextrine	1.10	10.0	15
	Pine oil	0.69		
Fe conditioner	Sodium resinate	3.20	5.0	65
	HF	0.24		
	Pine oil	0.76		
Fe cell			5.4	20

Metallurgical Results

Product	Wt, Pct	Spodumene Pct	Spodumene Units	Spodumene Dist.	Fe_2O_3, Pct	(1) Li_2O, Pct	(2) Li_2O, Pct
Heads	100.0	22.0	22.0	100.0	0.89	1.90	1.30
Oversize	0.1	75.0	0.1	0.5		5.80	5.80
Bowl overflow	3.8	3.0	0.1	0.5	1.02	0.35	0.74
Rake overflow	3.2	3.0	0.1	0.5	0.68	0.35	0.87
Gangue froth	72.0	7.0	5.0	23.0	0.23	0.70	0.64
Iron froth	1.5	59.0	0.9	4.1	7.06	4.40	3.50
Spodume conc	19.1	81.0	15.5	71.4	0.47	6.10	6.00
Total	99.7		21.7	100.0			

Test 14

Operating Conditions

Feed:—½ in. Lab. No. 985, 12.5 pct spodumene, 0.35 pct Fe_2O_3, fed at 325 lb per hr. Mill discharge —28 mesh.

Equipment	Reagent	Quantity, Lb Per Ton	pH	Solids, Pct
Rod mill	NaOH	4.80		65
Rougher conditioner	NaOH	0.17	11.1	50
	Dextrine	0.98		
	Amine	0.68		
	Pine oil	0.90		
Rougher cell	NaOH	0.26	11.0	20
Cleaner cell	Dextrine	0.98	10.5	15
	Pine oil	0.46		
Iron conditioner	Sodium resinate	2.16		
	HF	0.70		65
	Cresylic acid	0.52		

Metallurgical Results

Product	Wt, Pct	Spodumene Pct	Spodumene Units	Spodumene Dist.	Fe_2O_3, Pct	(1) Li_2O, Pct	(2) Li_2O, Pct
Heads	100.0	12.7	12.7	100.0	0.35	1.15	1.15
Oversize	0.1	80.0	0.1	0.7		6.05	6.00
Bowl overflow	7.7	5.0	0.4	2.8	1.64	0.50	0.87
Rake overflow	2.3	6.0	0.1	0.7	0.96	0.60	0.81
Screw overflow	0.4	12.0			1.00	1.10	1.80
Gangue froth	77.0	4.7	3.6	26.0	0.19	0.50	0.42
Iron froth	0.6	53.3	0.3	2.2	11.00	4.30	3.96
Spodumene conc	11.8	80.0	9.3	67.5	0.65	6.05	6.44
Total	99.9		13.8	99.9			

(1) By using curve showing percent Li_2O vs percent sinks in acetylene tetrabromide.
(2) By actual chemical analysis.
Distribution based on percentage of sinks in acetylene tetrabromide.
Chemical analyses by Foote Mineral Co.

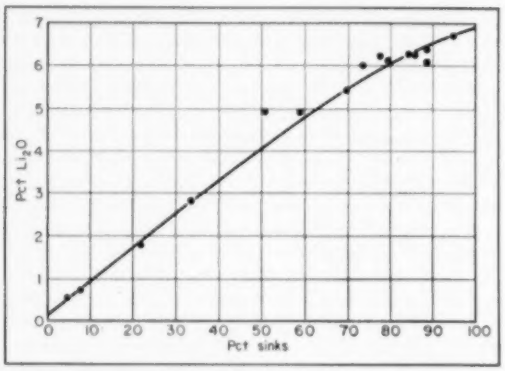

Fig. 2—Percentage of sinks in a given sample compared with percentage of Li_2O.

in interesting quantities was recognized and a method evolved to recover it.

Table IV shows the results obtained in pilot plant tests No. 2 and 14.

Heavy Liquid Control Method

The use of acetylene tetrabromide as a laboratory control aid is worthy of mention here in view of its extensive use in this investigation. The liquid has a specific gravity of 2.96. The only major constituent of the spodumene ores having a specific gravity higher than 2.96 was spodumene itself. It was found that −20 mesh ore samples, when placed in acetylene tetrabromide, resulted in a sinks product averaging 98 pct spodumene, the remaining 2 pct consisting of traces of cassiterite, horneblende, tourmaline, apatite, pyrite, and numerous others. Therefore, for all practical control purposes, the percentage of sinks in acetylene tetrabromide was the actual percentage of spodumene in the product.

A method was evolved in which the test samples were weighed, placed in acetylene tetrabromide contained in centrifuge tubes, and centrifuged for 10 min. Centrifuging brought about excellent separation of gangue minerals as floats and spodumene as sinks. Floats and sinks were then easily separated by a simple pouring technique, filtered, washed with benzene to remove excess tetrabromide, dried and weighed.

A graph, Fig. 2, was then drawn in which percentage of sinks in a given sample was plotted against percentage of Li_2O contained in the sample. Li_2O analyses for this graph were furnished by Foote Mineral Co. By obtaining the percentage of sinks in acetylene tetrabromide and reading the corresponding Li_2O value from the graph, it was possible to obtain a reasonably accurate Li_2O analysis.

This method was used as a control on laboratory batch tests and pilot plant tests. All products were quickly and easily evaluated from a lithia standpoint without the long and costly chemical analytical procedure for lithia determination. From 12 to 18 Li_2O determinations per 8-hr shift could be made by semi-skilled operators using this method. In addition to its use as laboratory control, the method could easily be adapted in commercial plant operating control.

Conclusions

The two flotation separations described in the foregoing pages produced spodumene concentrates from Kings Mountain ores on a continuous pilot plant scale. The spodumene concentrates contained an average of 6.0 pct Li_2O and 0.45 pct Fe_2O_3 with a recovery of 70 pct available spodumene. If the iron removal step was not carried out the recovery of spodumene was approximately 75 pct. The process was successful on feed ground as coarse as 20 mesh. Weathered ores required light attrition scrubbing for satisfactory separation, but this was carried out in an acceptable manner by milling at high density with a high caustic addition.

The process is not recommended for use on ores containing less than 15 pct spodumene because recovery tends to drop off as spodumene content in the feed decreases. This is due to the fact that the gangue froth product inherently contains 3 to 5 pct spodumene, and this becomes an increasingly high percentage of the total distribution as the spodumene content of the ore decreases.

There were no particularly difficult operating problems. The two most important operating points, and the ones which might easily be overlooked, were proper pretreatment of weathered ores and strict maintenance of high pulp density in the conditioner before iron-mineral flotation.

The most difficult mineral to cope with was horneblende. Spodumene and horneblende are closely related mineralogically and exhibited similar reactions to the above described process. To remove horneblende satisfactorily, if it were encountered in appreciable amounts in the ore, it would probably be necessary to employ both flotation and magnetic separation.

Acknowledgments

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Research on the Cutting Action of The Diamond Drill Bit

by E. P. Pfleider and Rolland L. Blake

IT is generally believed that the amount of diamond drilling will increase appreciably in the next decade, as the search for minerals throughout the world becomes more difficult and intense. An attendant problem may be one of short diamond supply, resulting in higher bit and drilling cost. With this background, the U. S. Bureau of Mines[1] and the School of Mines at the University of Minnesota[2] have established comprehensive research programs in diamond drilling. One of the several aims is the design of a more efficient bit, which would lower diamond consumption and increase rate of advance, both essential in reducing drilling costs.

The objective of the specific research problem[3] discussed in this paper was an investigation of the cutting action of the diamonds set in a diamond drill bit, cutting action meaning the manner in which the diamonds cut or loosen the minerals in the rocks being drilled.

In the literature on cutting action such descriptive terms are used as: *grinding, wearing, cutting, breaking, shearing, scraping, melting,* and *chipping.* These actions were seldom described or defined. Grodzinski[4] describes the cutting action of a single diamond in the shaping of certain types of material as "breaking out chips of the material." Brittle materials break as small separate chips, and tough materials, because of heat generated, give a continuous chip. Deeby[5] said about diamond drills: "When diamonds are forced into the formation and rotated, they either break the bond holding the rock particles together, or they cause conchoidal fracture of the rock itself. The former action occurs when drilling in sandstones, siltstones, shales, etc. and the latter action when drilling in chert, flint, or quartz." He said that diamonds cut on the "grinding principle" but he does not define or elaborate on this action. The cutting action of diamonds on glass was first investigated about 1816 by Dr. W. H. Wollaston, an English physicist.[4] The best glass-cutting diamonds have a natural or artificially rounded cutting edge. This edge first indents the glass and then slightly separates the particles, forming a shallow and nearly invisible fissure. Since none of the material is removed, this action is one of splitting rather than cutting.

No other reports of research work on the cutting action of the diamond were found, and further work was considered justified and advisable.

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It is impractical, even if possible, to observe directly the cutting action of a diamond drill bit in rock; therefore it was necessary to devise an indirect method. It was believed that a study of the following three observations would lead to a better understanding of the cutting action: 1—the appearance of the minerals or rock surface in the bottom of the hole, 2—the size, shape, and other characteristics of the drill cuttings, and 3—the condition of the diamonds in the bit.

The cutting action in a particular rock probably varies with bit pressure and speed. If the bit were slowly lifted off the rock, the effect of decreasing pressure might obliterate those bottom hole characteristics that are specific at the test pressure. Likewise, if the drill were stopped with the bit still in contact with the bottom of the hole, then decreasing speed effects would tend to obliterate the characteristics at the set test conditions. Therefore, in order to preserve those cutting effects impressed on the rock at test conditions, it seemed necessary to lift the bit off the bottom of the hole almost instantaneously once drilling conditions, i.e., revolutions per minute, pressure, and water flow became constant.

In addition to observing the cuttings, the bit, and the bottom of hole, it seemed desirable to collect some quantitative data for purposes of correlation with the observations and for a record of bit performance. Consequently such data as revolutions per minute, force applied, and rate of advance of the bit were recorded.

Six rock types, listed in Table I, were chosen for the tests. It was felt that these rocks had most of the variable characteristics of texture, bonding, and mineral hardness met in the common rocks generally being drilled. The sandstone was so poorly cemented as to be friable, even though most of the cement was silica. The limestone, though well cemented, was quite porous.

Table I. Characteristics of the Rocks Tested

Rock	Source	Texture		Cementation		Minerals	
		Coarse	Fine	Good	Poor	Hard	Soft
Granite	Rockville, Minn.	X	—	X	—	X	X
Trap Rock	Dresser Junction	—	X	X	—	X	X
Taconite	Babbitt	X	—	X	—	X	X
Marble	—	—	X	X	—	—	X
Limestone	Bedford	X	—	X	—	—	X
Sandstone	Hinckley	X	—	—	X	X	—

Originally it was planned to conduct the tesk work with a full-scale drill unit, using EX bits, ⅞-in. core, 1¼-in. OD. The drill worked well, but was too cumbersome for rapid, accurate drilling of many short holes (1½-in.) in varied rock types. A new

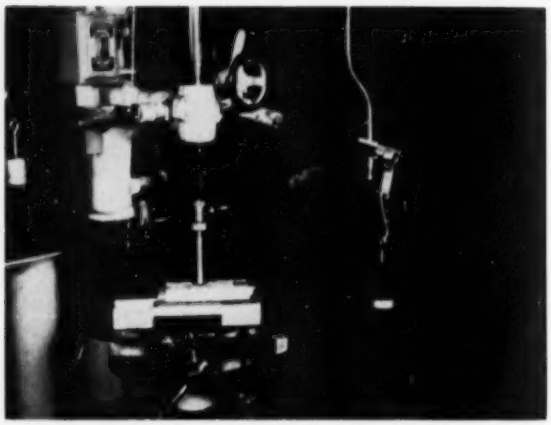

Fig. 1—Truco unit set up in drill press.

technique, employing a drill press and ⅝-in. Truco core bit, was developed to replace the larger drill, which was used thereafter only for check purposes.

The Truco Senior drilling unit was mounted in a drill press, see Fig. 1, having a ½-in. shank capacity and powered by a 0.94 hp electric motor through a gear transmission system and belt drive. The drill press could be varied between 80 and 305 rpm.

The two Truco F-1 bits used in these experiments were of 1-in. OD and ⅝-in. core diam. Both bits were surface-set, double roundnose, and had two waterways. The matrix was composed of sintered tungsten powder, and the diamonds were of the finest quality West African bortz, running approximately 100 per carat in size. A photo of the crown of one of these bits is shown in Fig. 2 and the pattern of their diamond settings is sketched in Fig. 3. The diamond wear during the course of the work was very slight, and bit condition is considered a constant for purposes of comparing the other factors.

The test blocks of the various rock types were approximately 3x3x8-in. in size and were drilled on four sides, see Fig. 4. They were placed in a galvanized tin trough, held in tightly by wooden wedges, and then clamped in the drill press bench-vise. The tin trough caught the water and most of the cuttings. The overflow of water and fine cuttings was caught in a large container on the floor.

A binocular microscope was used to examine the cuttings, the drilling surface at the bottom of the holes, and the condition of the bit. The magnification commonly used was X21.2; consequently the depth of the holes was held to ½ in. or less. A Leitz macro-camera was used for most of the photographs.

Bit rpm was one of the controlled variables. Tests were run at the minimum and maximum speeds of 80 and 305 rpm, and occasionally the intermediate setting of 170 rpm was used. It will be appreciated that equivalent linear speeds of 17 to 65 ft per min are much lower than the 300 to 450 ft per min obtained with an EX bit when rotating at the usual drilling speeds of 1000 to 1500 rpm. Such a variation in linear speeds may have considerable effect on the cutting action, although microscopic examination of particles caught during drilling at speeds of 80 and 305 rpm, respectively, showed little difference in size or shape of cuttings.

Force on the bit was the second controlled variable. The drill press feed was manual, activated by means of a lever arm, see Fig. 1. Constant, controlled force on the bit was obtained by hanging weights on the lever arm and calibrating so that the thrust could be increased by increments of 25 lb. By using weights in this manner, the operator was able to lift the bit quickly off the bottom of the hole with the lever arm when operating conditions became constant. The drill press was calibrated for bit forces of 0 to 1000 lb when the arm was in its normal horizontal operating position.

Bit Performance

The bit performance curves drawn from the test data obtained in the drilling of the six rock types are shown in Figs. 5 and 6. These curves do not express the cutting action directly. However, they do permit comparison of the cutting efficiency for the same bit in different rocks, and, of greater importance, represent the measurable effect of various phenomena noted in the study of cuttings and of the bottom of the hole. A discussion of the more significant results follows.

Granite: The drilling rate increased almost proportionately to changes in both force on bit and rpm of bit. The drill stalled at 550 lb and 305 rpm, necessitating a reduction to 170 rpm to attain bit forces up to 1000 lb. Had it been possible to test at speeds up to 1000 rpm, it seems unlikely that the increase in rate of advance would have held proportional to increased speed of rotation. In other words, rate of advance vs rpm curve would have changed from a straight line relationship into an ever flattening curve. The explanation for this probably lies in the fact that the cuttings are ground increasingly finer before being washed away from the faster moving diamonds; hence the drilling efficiency decreases.

Trap Rock: The advance in trap rock at 80 rpm was similar to that in granite and taconite. Drilling was discontinued at 700 lb because most of the spaces between the diamonds on the bit crown were plugged, and the bit speed and drilling rate were reduced. The drilling rate at 305 rpm again dropped off because of this plugging of the bit. At 500 lb the bit nearly stopped rotating. It was cleaned and temporarily gave good results, but at 600 and 650 lb plugging again lowered the rate of advance.

Taconite: The drilling rate in taconite at 80 rpm showed an increase proportional to bit force, and

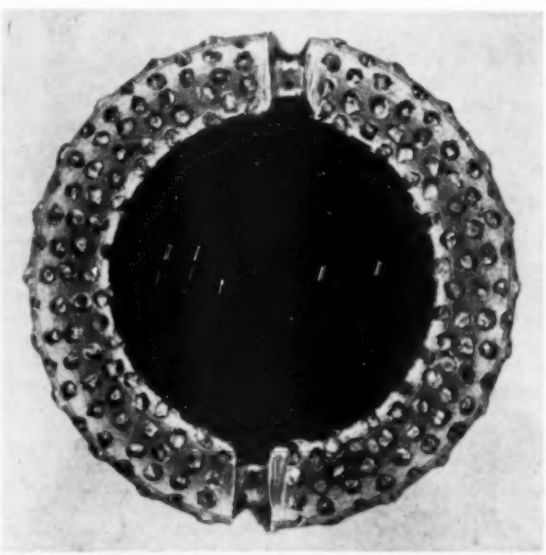

Fig. 2—Truco bit F-1. About three times actual size.

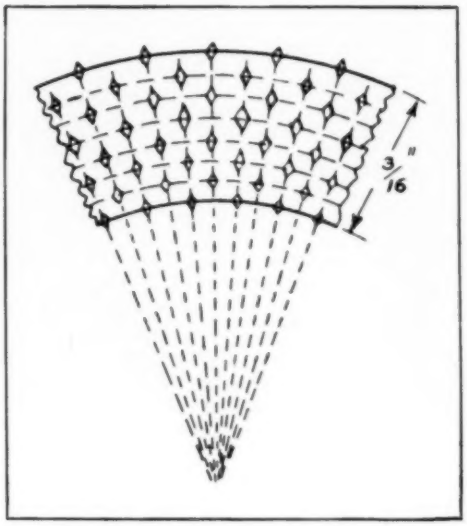

Fig. 3—Diamond arrangement in Truco F-1 bit.

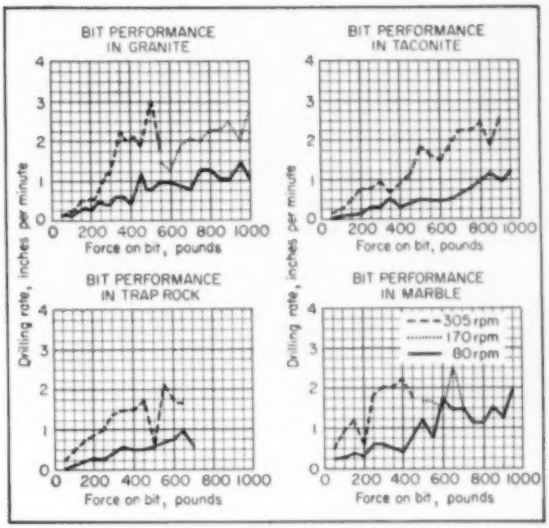

Fig. 5—Bit performance for Truco F-1 bit in drill press set-up.

gave a curve very similar to that observed in drilling granite. However, the rate of advance at 305 rpm did not increase in a direct ratio to the increase in bit speed from 80 rpm, as it did in drilling of granite. The reason for the disproportionate advance at the higher speed, 305 rpm, as compared with the rate at 80 rpm, cannot be explained by the facts at hand. There was no tendency for the bit to plug, and it was possible to drill at conditions up to 900-lb bit force, giving a penetration of 2⅝ in. per min, before the revolutions per minute slowed down appreciably.

Marble: The bit performance in marble was very poor considering the fact that marble is composed of recrystallized calcite and/or dolomite, both of which are much softer than the quartz and feldspar in granite. Furthermore, deviations from a smooth curve were greater for drilling in marble than for drilling in granite. These results may be explained by the tendency of the cuttings to cling to the crown of the bit and to build up a cake on the bit crown. The word *cake* in this paper will refer to the fine powder of a mineral, s, that agglomerates and covers the grooves and/or ridges and may cling to the matrix of the bit, thus plugging the spaces between the diamonds. The bit was cleaned whenever this condition was noted, but it was not possible to prevent this caking during the running of individual tests, even though the water flow was considerably increased. Warm water was tried, but no consistently improved results were obtained. The maximum drilling rate before stalling was about 2¼ in. per min at both 170 and 305 rpm, as compared to about 3 in. per min for granite.

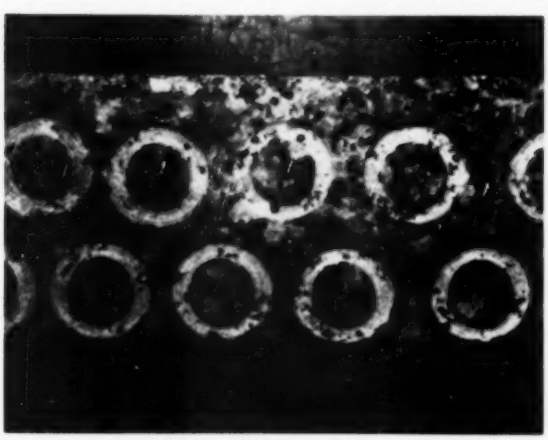

Fig. 4—Arrangement of holes on one side of a columnar block of granite. Holes are about 1/4 in. deep.

Limestone: The drilling rate in limestone compared favorably with that in sandstone at low bit forces. At bit forces exceeding 250 to 300 lb, spaces between the diamonds on the bit crown became filled with mashed cuttings, and there was an involuntary reduction in revolutions per minute. As with marble, the test results were erratic and were further evidence that the chief cause of poor performance for this particular bit in soft rocks is the caking of the bit crown by the cuttings. This caking did not occur in drilling granite or sandstone. Force on the bit seemed to be the principal cause of the caking action in limestone, there being a tendency to mash the cuttings into a cake at the critical force of about 200 lb. Here again a generous flow of warm water was used in an attempt to eliminate the caking action. The bit performance curve for 80 rpm indicates that warm water may have relieved the situation during drilling at 250-lb force, but not at a force of 300 lb.

Sandstone: Drilling rates in sandstone, as in granite, were roughly proportional to increases in bit force and revolutions per minute when within the power limits of the drill unit. There was no tendency of the bit to plug by caking, and maximum rate of advance appeared to be about 9 in. per min, or three times the rate obtained in granite under similar conditions.

In general, advance for this particular Truco bit design in the various rock types appears to be roughly proportional to revolutions per minute and bit force, as long as the water can carry the cuttings away from the bit crown rapidly enough to prevent regrinding or plugging of the spaces between the diamonds. Plugging occurred in the finer grained rocks, marble, limestone, and trap rock, particularly if soft minerals were present. It was evident especially at the higher bit speeds. There appears to be a rela-

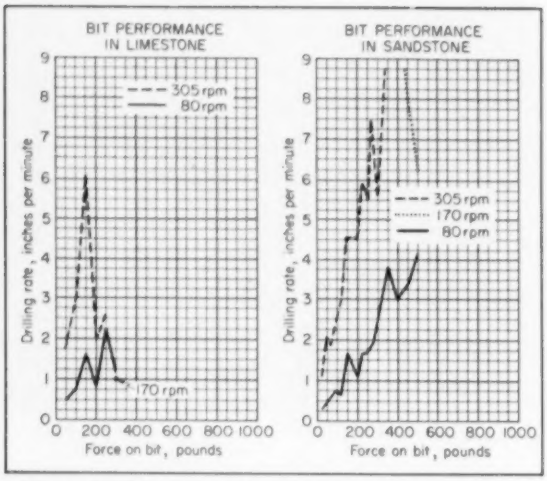

Fig. 6—Bit performance of Truco F-1 bit in drill press set-up.

tionship between plugging and a critical force on the bit, ranging from 200 lb for marble and limestone to 350 lb for trap rock.

Examination of Bottom of Hole

Most striking under microscopic examination of the annular surface at the bottom of the holes, see Figs. 7a through 12, were the concentric, alternating ridges and grooves in the rock. They were usually well defined at slower bit speeds and forces but gradually became indistinguishable when bit speeds and pressures increased or when the bit became plugged. Another characteristic was the frosted or sugary appearance of the annular surfaces. This became more pronounced at higher bit forces, especially in granite. *Frosting,* in this sense, is believed to be caused by the refraction and reflection of light from irregular surfaces of the minerals, as well as from minute fractures beneath the exposed surfaces of the minerals.

Granite: In an examination of the newly-cut surfaces of the holes drilled in granite, see Figs. 7a and 7b, the quartz appeared conchoidally fractured, with a frosted appearance. The quartz seldom stood in ridges, which were broken off. Minute fractures extended in all directions deep into the mineral. Very little separation occurred along these fractures. Thus free particles were not formed deep in the minerals ahead of the diamonds. This fracturing might be likened to that which occurs when an ice-pick splits the ice ahead of it without separating the ice into pieces. It is also very similar to the fissures noticed by Wollaston in cutting glass with diamonds. As would be expected, the fracturing appears to extend deeper at higher bit forces.

Feldspar also was fractured or shattered beneath the mineral surfaces, though not as pronouncedly as was the quartz. It often broke along cleavage directions. Feldspar stood in ridges better than quartz, probably because it was not as brittle or hard. If the cleavages of the feldspar were nearly perpendicular to the direction of bit advance, these ridges were often sheared off low, along the cleavage.

Biotite usually stood in good ridges and did not appear fractured in depth. Ordinarily the flakes separated along their basal cleavage. The biotite was cut clearly when at right angles to the cleavage, especially in the grooves. Ridges in which the cleavage was vertical showed smoothly cut edges. Those with inclined cleavage had ragged edges and often had minute *books* of mica plucked out. Biotite was the first mineral to show a mashed effect, the finely ground particles, slightly moistened with water, being sufficiently cohesive to be pressed into a cake. At 80 rpm and 475-lb bit force some of the biotite in the grooves did not break away, but became crushed and mashed into a cake beneath the diamond points. However, this caking was never sufficient to plug the bit or appreciably affect its drilling action. At all bit forces greater than 475 lb some biotite was mashed. Quartz and feldspar did not appear as a mashed cake on the bottom of the hole at any bit forces.

The cutting action in granite, then, seems to be a shattering at depth of the hard and brittle minerals, such as quartz and feldspar, forming a network of minute fractures. This splitting often occurs along cleavage planes, as in feldspar. The fractures aid the succeeding diamonds in breaking out particles toward the free faces, or exposed surfaces. A soft, platy mineral, such as mica, is separated along its cleavage and is broken at right angles to this cleavage. Many of the mineral particles are ground or broken finer before they are washed free from the action of the bit. Such fine particles from minerals like feldspar may be mashed into a flake, whereas those from the soft minerals like mica are mashed into a cake. The word *flake* in this report will refer

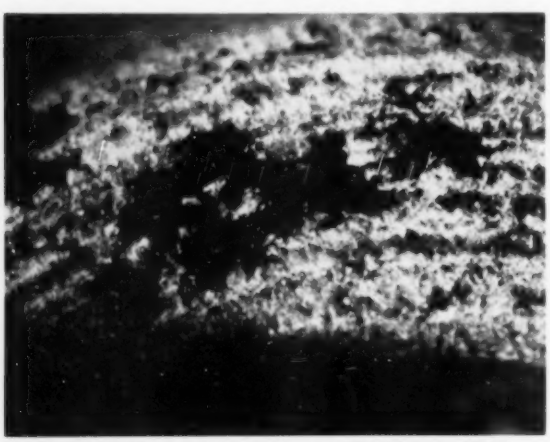

Fig. 7a—Bottom of hole in granite, X12, 80 rpm, 500-lb force, 3/4 in. per min.

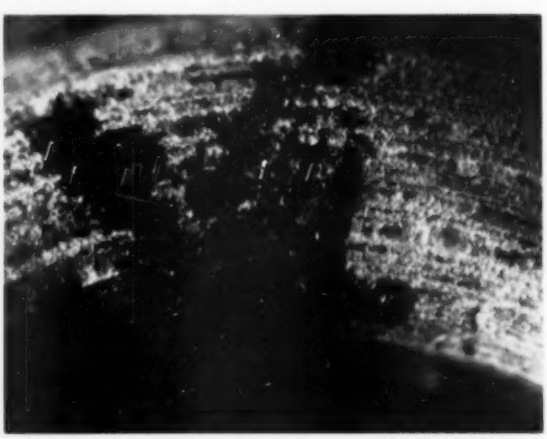

Fig. 7b—Bottom of hole in granite, X12, 305 rpm, 100-lb force, 1/5 in. per min.

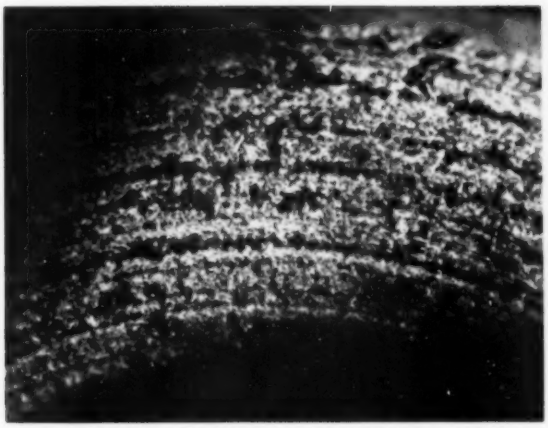

Fig. 8—Bottom of hole in trap rock, X12, 305 rpm, 150-lb force, 3/4 in. per min.

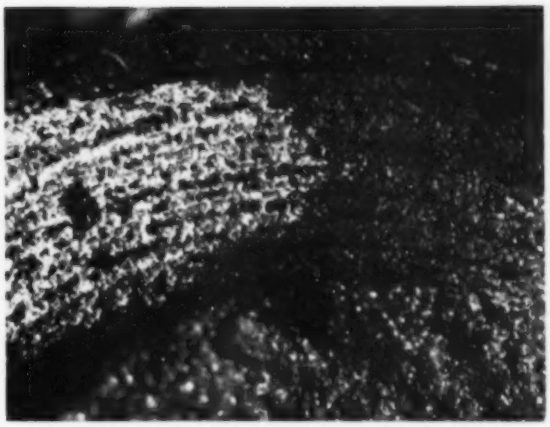

Fig. 9—Bottom of hole in taconite, X12, 305 rpm, 850-lb force, 1 7/8 in. per min.

to *rock flour* or mineral, s, that has been mechanically mashed into a thin, slightly curled chip. Cake plugs the bit when in sufficient quantity, and slows or stops the drill; flakes apparently have only a slight effect on cutting efficiency.

The bottoms of some 69 holes in granite were compared to determine what visible effect various bit speeds and forces have on the cutting action. These effects are summarized in Table II.

Trap Rock: Grooves and ridges usually were fair to well-developed in the holes drilled in trap rock, as evident in Fig. 8. A dark platy mineral, like biotite, broke along a basal cleavage, as did the biotite in granite. Soft silicates mashed and formed cake, which often plugged the bit. This mashing and caking was not so pronounced as that in marble and limestone. Hard silicates again fractured ahead into the minerals, but not so deeply as in quartz. In general the holes drilled in trap rock looked much like those drilled in granite.

Table II. Comparison of Effects on Cutting Action of the Diamond Bit on Granite as Caused by Increase of Bit Speed, RPM, and Bit Force

Increased Bit Speed	Increased Bit Force
1—Greater impact of diamonds possibly resulting in increased depth and intensity of fracturing.	1—Greater compression by diamonds resulting in increased depth and intensity of fracturing.
2—No increase in the number of fine particles remaining attached to the rock surface.	2—Increase in the number of fine particles remaining attached to the rock surface, resulting in more frosted appearance.
3—No further penetration of diamonds into the rock, but rather the removal of more cuttings per unit of time because of increased linear speed.	3—Deeper penetration of rock by diamonds, cutting out more and/or larger particles per unit of time.
4—At low bit forces, higher bit speeds resulting in smoother mineral surfaces. Less noticeable effect at high bit forces.	4—At low bit forces, higher bit speeds resulting in smoother mineral surfaces. Less noticeable effect at high bit forces.
5—No effect on ridges.	5—Lower and narrower ridges.

Taconite: The bottom of a hole drilled in taconite is shown in Fig. 9. The dark mineral is magnetite, and the highly reflective area is composed of silicates. Magnetite showed an irregular or hackly fracture and a tendency to break out in tabular chips. Its grooves and ridges were poorly developed, probably because this brittle mineral fractures easily and crumbles beneath the diamonds. Fracturing was very shallow in magnetite. It did not form a cake, presumably because of its hardness and tendency to crumble rather than to mash.

Silicates in the taconite showed a deeply fractured appearance similar to that of quartz and feldspars in granite. Ridges were only slightly fractured. Both grooves and ridges were fairly well-developed at lower bit forces but became indefinite at higher bit forces. There was a slight tendency for some of the soft silicates to form flakes, but not to cake.

In areas where silicates and magnetite were intimately mixed, each mineral cut as described above, but ridges and grooves usually were well-developed. Although taconite is a tough rock to drill, this quality appears to be imparted more by the silicates than by the magnetite.

Marble: A photograph of the bottom of a hole drilled in marble is shown in Fig. 10. Grooves were found to be shallow, and ridges were low in all holes. When visible, grooves always had a frosted appearance from fragments fractured but not completely broken free. Ridges were usually frosted, but occasionally revealed the dark, very fine, recrystallized texture of the marble.

Fracturing of the marble did not extend deeply or vertically, as in the quartz and feldspar, but was shallow and gently inclined. Grooves were often filled with the cake mentioned previously. It had a white, chalky appearance, and in several holes was thick enough to cover both ridges and grooves with a smooth layer. Tiny traces of the diamond points in this cake suggest that the bit also was plugged with cake, riding high on the contact of both cake accumulations and with only the tip of the diamonds scratching the cake on the bottom of the hole. The low drilling rates in marble support this conclusion.

It is believed that flocculation of the cuttings beneath the bit may have aided the caking effect. When a 0.1 pct, by weight, quebracha solution was used as a dispersant, the caking effect was low to medium in comparison with previous holes, and drilling results suggest that this dispersing agent prevented some caking.

The cutting action in marble seemed to be a shallow shattering of the mineral particles, producing very fine angular fragments easily mashed into a cake, and even into large flakes, some of which

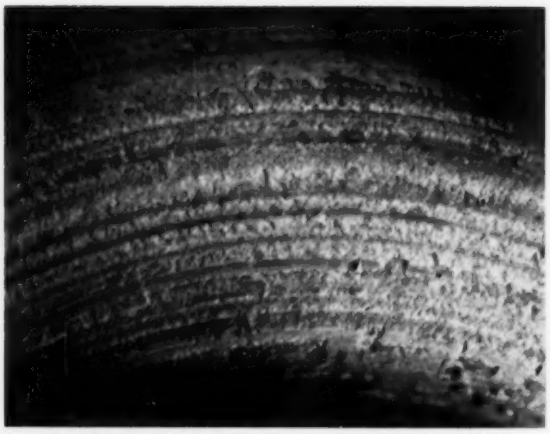

Fig. 10—Bottom of hole in marble, X12, 305 rpm, 150-lb force, 7/16 in. per min.

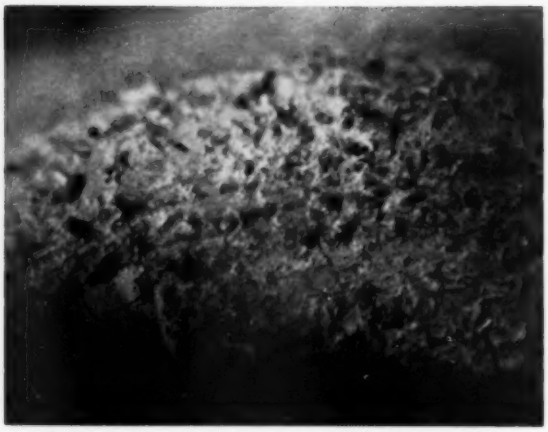

Fig. 11—Bottom of hole in limestone, X12, 305 rpm, 200-lb force, 1 7/8 in. per min.

were observed resting on the bottom of the hole. As bit force increased, the diamond points penetrated further into the soft calcite and accentuated the tendency to cake, 1—by cutting increasingly greater amounts of calcite and 2—by decreasing the clearance space between diamonds so that the wash water could not remove the soft particles before they become mashed between the bit and the bottom of the hole.

Limestone: Fig. 11 is a photograph of the bottom of a hole drilled in the oolitic limestone. Grooves and ridges varied in condition from fair to entirely missing. Cake is abundant, as it was in the marble, and a large thick piece may be seen in the lower left corner of the photograph.

The cutting action in oolitic limestone is a very shallow fracturing of the grains and their cement. They are so soft that they yield easily and do not fracture deeply. A massive limestone probably would be cut more like a marble, wherein the mineral grains are fractured evenly rather than being plucked out. The degree and manner of caking seems about the same in limestone and marble.

Sandstone: Sandstone showed no grooves and ridges, see Fig. 12. Two factors contributed to this: 1—the diamonds did not penetrate quartz grains very deeply, but seemed to ride on the diamond points, and 2—the poorly cemented grains were easily separated. Trails of finely powdered quartz occurred where the diamond points rode on the quartz. The dark spots in the photographs are shadows in the many cavities. Some of these cavities were original pores not filled by the cementing media; others were formed by the plucking out of grains or aggregates of grains.

Much of the drilling broke the quartz grains loose by shattering their cement, but over half the grains were broken. As the bit force increased, the percentage of quartz grains broken rose from a low of 50 pct to a constant of 75 to 80 pct at forces of 100 lb and greater.

The cutting action in sandstone was a deep fracturing of the quartz grains, like that occurring in the quartz of a granite. This fracturing broke the quartz grains if the silica cement held them tightly, or it broke the cement itself. Some of the grains and cement were pushed forward into cavities, where they were broken up further by the bit. This porous texture presents many free faces to which the fractured quartz could be broken, and its effect on the cutting efficiency is evidenced strikingly in the bit performance results.

From a study of each of the six types of rocks drilled, it is apparent that each mineral is cut in a fairly definite manner, depending upon its hardness, toughness or fibrous structure, cleavage, tenacity, and probably several other physical properties. The cutting action in rocks is less definite than that in minerals because rocks are usually heterogeneous aggregates of different minerals. The cutting action thus becomes modified by variations in mineral composition, texture, porosity, and degree and type of cementation.

Microscopic study and screen analysis of the drill cuttings aided and confirmed the interpretation of the cutting action as described above.

Shape of Cuttings

Granite: Quartz cuttings were angular, conchoidally fractured fragments, seldom internally shattered. Feldspar presented an irregular broken appearance. When cleavage was visible, the fragments were tabular with jagged edges. The feldspar produced some thin curled flakes at higher bit forces, presumably owing to a mashing action. Biotite cuttings were irregularly edged sheets of varying thickness, from those nearly transparent to opaque books about 0.5 mm thick. Some of the thin sheets were bent, but very few flakes of biotite were formed by a mashing action.

Trap Rock: The cuttings of trap rock contained numerous light greenish-gray fragments of frosted appearance, probably silicates. There were also many thick, curled, mottled black and green flakes. Although the fine rock flour mashed into a thick cake in the bottom of the hole, it did not collect into aggregate lumps as it did in the cuttings of marble and limestone.

Taconite: Magnetite occurred as flat, hackly fractured chips, and occasionally as very tiny flakes. There were some angular quartz fragments and many green and colorless silicate fragments, about half of which had been mashed into flakes.

Marble: Marble cuttings consisted of a few fragments, up to 0.5 mm in size, but mostly of fine rock flour. The particles often clung together, even in a dried state, to form aggregates. Perhaps these aggregates represented part of the cake that continuously filled the grooves in the bottom of the hole. There were many curled, shiny flakes, as shown in Fig. 13.

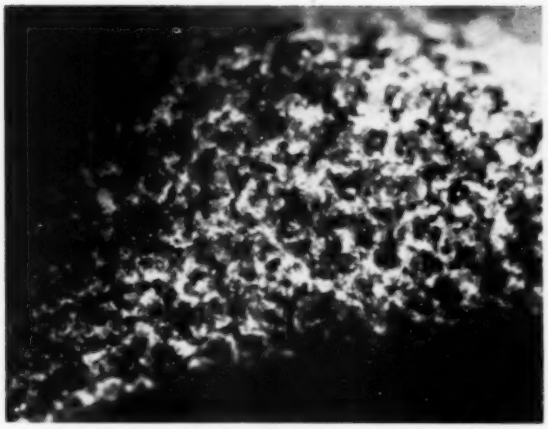

Fig. 12—Bottom of hole in sandstone, X12, 80 rpm, 75-lb force, 7/16 in. per min.

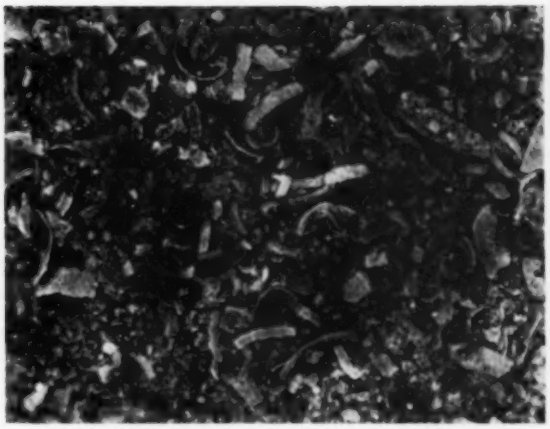

Fig. 13—Cuttings from marble, X12, 80 rpm, 100-lb force, 1/4 in. per min.

Limestone: Oolitic limestone cuttings contained buff-colored colites, rock flour, and broken oolite fragments. Some oolites were still cemented in aggregates. The fine particles aggregated into lumps, thereby giving the impression that a coagulant had been used.

Sandstone: Sandstone cuttings showed very jagged conchoidally fractured pieces of quartz up to 1 mm in diam. Crystal faces were visible on some fragments. Cuttings resembled many tiny chips of glass.

Size of Cuttings

The consensus of opinion in the diamond drilling profession is that a relationship exists between speed of drilling advance and size of cuttings. Samples were caught during nine of the tests drilled by the Truco bit, 1-in. OD, and 14 test runs in granite with an EX bit, 1.5-in. OD. These samples were sized by screening, and some of the results are presented in Table III.

The following observations are made on the basis of this preliminary work, although much more research should be done on this phase of the problem in order to develop definite conclusions.

1—A rough correlation exists between rate of advance and size range of cuttings, i.e., the higher the rate of advance, the coarser the particles. The results obtained in sandstone are particularly significant in this respect.

This relationship is similar to that found by Ertl and Burgh in their test drilling of the oil shales at Rifle, Colo., with percussion drills. Their conclusion was that "the speed of percussion drilling varies directly with the coarseness of cuttings produced."[6] They further stated that rock drilling speeds could be increased by improving the design of rock bits to produce coarser cuttings and by removing the coarse cuttings as rapidly as produced. Much the same statement can be made of diamond bits and drills.

2—During drilling in granite, more fine particles, −270 mesh, were formed at the higher bit speeds and the lower bit forces, as would be expected.

3—The average weight percentage of −270 mesh, 0.053 mm, cuttings from the Truco bit in all six rock types was 63.7 pct. Cuttings from granite ranged from 65 to 78 pct −270 mesh.

4—Cuttings from granite ranged from 79 to 88 pct −270 mesh when drilled with the standard EX double roundnose bit having diamonds running 32 stones per carat. Surprisingly, these figures are 10 pct higher, for the finest fraction, than those produced by the Truco bit, which has much smaller stones. However, the EX bit was rotating at speeds of 800 to 1200 rpm, in contrast to 80 and 305 rpm for the Truco bit. The finer particles produced by the EX bit are probably accounted for by this higher bit speed, together with the fact that there are many more individual diamonds in the EX bit than in the Truco bit, subject to a lower unit force.

Interpretation of Cutting Action

Certain concepts of the cutting action of the diamond drill bit have been developed from the interpretation of the research work reported herein. A discussion of these concepts follows.

Breaking of Rocks and Minerals: Inasmuch as most rocks are composed of mineral particles of varying size, shape, and composition, rocks are essentially heterogeneous. They will break more easily along bedding, lamination, and grain boundaries than across grains or perpendicular to these directions.

Each mineral particle of a rock, however, is a homogeneous substance and will break according to its internal physical characteristics. Dana states that the crushing, or breaking, characteristics of minerals depend upon cohesion and elasticity.[7] These characteristics, in turn, are exhibited in such physical properties as hardness, tenacity, brittleness, fracture, and cleavage. Cohesion represents the force of attraction between molecules of a given substance; elasticity is the force tending to restore the molecules under strain to their original positions. Both these internal forces must be overcome when minerals in a rock are broken into fragments.

In diamond drilling, the *force on the bit* causes diamonds to penetrate the rock, and minerals, by a compressive force. This force sets up internal stresses. In brittle minerals or rocks, these stresses will not be relieved readily by strain, that is, deformation, but rather by the formation of tension or shear fractures.

The *rotary bit speed* causes two actions by the diamonds on the rock or minerals: 1—an impact, and 2—a shearing force. The first stage of an elastic impact is compression; the second stage an elastic restoring force. Both stages may be relieved by the development of tension and/or shear fractures. The shearing force, likewise, may cause these fractures.

Breaking to Free Faces: In drilling rocks with

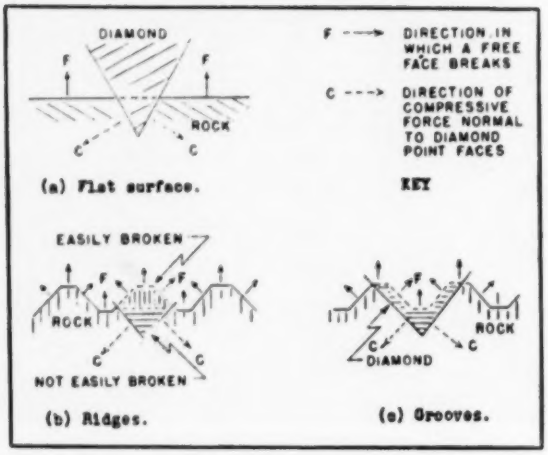

Fig. 14—Diamond point penetration of various surfaces.

limited porosity, those particles being formed by the cutting action must break toward free faces, a *free face* being defined as an exposed surface. This principle of breaking the rock to free faces, illustrated in Fig. 14, seems important in diamond drilling.

During drilling of a flat surface, only one free face is exposed, and the mineral will break with difficulty. Such a flat surface may be formed by well-worn diamonds. When diamonds are set so as to form alternate flat-top ridges and grooves, three free faces are exposed. This should permit the diamonds to break out larger rock particles and thereby increase drilling efficiency, particularly if the bit design permits ready removal of these coarser cuttings. A setting of diamonds in wide concentric grooves, wherein all the stones track in grooves cut by the preceding diamonds, would seem to be a less effective practice because of the difficulty in achieving appreciable diamond penetration.

Size and Protrusion of Diamonds: It is generally recommended 1—that small diamonds, with a slight protrusion from the matrix, be used for hard dense rocks and 2—that larger diamonds, well exposed, be employed in bits designed to drill the soft rocks such as limestones, marbles, and shales. To a large degree, the poor bit performance in the soft rocks during these experiments was undoubtedly a result of using small diamonds in the bit. The tendency to cake was accentuated by the slight clearance between the individual diamonds and between the matrix and the bottom of the hole. Larger stones would provide more clearance for cuttings to be washed away, besides forming larger-sized particles with less tendency to aggregate into cake.

The microscopic examinations of the cutting surfaces at the bottom of the drill holes showed that the hard minerals fissure and fracture below the depth of diamond penetration. It would seem, therefore, that good drilling efficiency can be obtained by using small diamonds for hard rocks, particularly if and when the speed of rotation is increased appreciably. Furthermore, the reduced protrusion of the smaller stones will decrease diamond breakage when drilling hard rocks and minerals.

Effect of Waterways: It was evident that the Truco bits would not have become plugged with cake so easily when drilling limestone if they had had more waterways. This conclusion is based on the fact that plugging originally commenced at a place on the bit nose just before the cuttings reached a waterway. In other words, a concentration of cuttings from nearly one-half the circumference of the bit built up a cake at this critical point. It is reasonable to believe that intermediate waterways would have eliminated this concentration, provided sufficient water was employed to maintain a good flow across the bit face.

In any event, for a given optimum water volume, the size and number of waterways must be such as to permit a good flow of water to pass between the rock and bit matrix while seeking paths between the diamonds. The purpose of this water is to carry the cuttings away immediately, in their coarsest state, as well as to cool the bit. Those cuttings that are not flushed away directly by the water passing across the bit face remain to be ground finer, until they are eventually overtaken by a waterway.

Testing of Bit Design

The authors feel that such a laboratory drill unit as described in this report can be employed very effectively in the development and testing of new bit designs for various rock types. The unit has several advantages over field testing procedures, namely:

1—Results may be obtained more quickly and easily, and with better control.

2—A microscopic study of the bottom of a hole in the small test block will aid in the interpretation of

Table III. Screen Analyses of Diamond Drill Cuttings

Rock Type	RPM	Bit Force, Lb	Advance, In. Per Min	Cutting Saved, Pct	Size Range, Wt Pct				
					+65 Mesh	−65 +100	−100 +200	−200 +270	−270
Truco Bits									
Granite	80	100	0.1	32	1	6	15	8	70
Granite	305	100	0.2	42	Trace	6	10	6	78
Granite	80	500	0.75	62	2	7	17	9	65
Granite	305	500	2.45	57	1	6	16	8	69
Trap rock	305	550	2.1	61	2	7	16	7	68
Taconite	305	700	2.2		1	17	20	8	54
Marble	305	400	2.25	57	4	6	10	4	76
Limestone	305	150	6.1	45	3	7	22	8	62
Sandstone	305	350	8.75	60	1	10	26	12	51
Ex Bit									
Granite	800	Pressure	0.8	85	1	2	10	7	80
Granite	1000	Control	1.2	82	1	2	11	5	81
Granite	1200	Inaccurate	0.6	58	1	1	7	6	85
Granite	1400		0.6	72	1	1	6	7	85

the cutting action of the test bit, suggesting corrective measures.

3—The small size trail bits should be less costly than experimental EX bits.

4—Drill cuttings may be collected very easily and used for sizing analysis and microscopic examination. Thus small-scale bits can be used to test radical designs and to suggest both minor and major changes. When a satisfactory model has been developed, a full-scale bit of this design could be tested in the field.

Summary

A study of bit performance, as well as the microscopic examination of bottom-hole conditions and the observation of the bit cuttings for the test conditions cited, led to the following interpretations as to the cutting action of the diamond drill bit:

1—Bit advance is approximately proportional to increases in rpm and/or force on bit during drilling at the slower rates. The efficiency drops off in the higher speed and pressure ranges as particles become more finely ground or the bit becomes partially plugged with a mineral which forms a cake.

2—The tendency to cake is common to the finer grained rocks, marble, limestone, and trap rock, containing such soft minerals as calcite and biotite.

3—Each mineral constituent of a rock is cut in a definite manner, depending upon its hardness, toughness, cleavage, and other physical properties. The total effect of this cutting action is modified in heterogeneous rocks by variations in mineral composition, texture, porosity, and cementation.

4—A rough correlation exists between rate of advance and size range of cuttings, i.e., the higher the rate of advance, the coarser the particle size.

5—The *force on the bit* causes diamond penetration by reason of compressive force; *rotary bit speed* causes an impact and a shearing force. These actions develop tension and/or shear fractures.

6—The principle of setting the diamonds to obtain drilling action that will break minerals to as many free faces as possible seems important.

7—Small diamonds, with slight protrusion, should be used for hard dense rocks; larger diamonds, well exposed and with ample water passages, should be employed in bits designed to drill soft rocks.

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Adsorption of Calcium and Sodium on Pyrite

by A. M. Gaudin and W. D. Charles

IN flotation lime is used to depress pyrite. For this purpose it is preferred to caustic soda. The low cost of lime and the widespread availability largely account for this preference. However, there is some evidence[1] that pyrite is more readily depressed by calcium than by sodium ions at the same pH. To measure the difference in adsorption of calcium and sodium, which is thought to lie at the basis of the differences in depressing action, radionuclides of calcium and sodium have been used. The experimental work has included an evaluation of the effect of dissolved oxygen, of the concentration of calcium or sodium, of the concentration of hydrogen ion, and of the anions present.

Preliminary work in the investigation entailed preparation of the pyrite, development of a technique for counting pyrite coated with Ca^{45} and Na^{22}, the radionuclides used, and development of an apparatus to study the adsorption of calcium and sodium on pyrite.

The main experimental work included calcium adsorption and sodium adsorption studies detailed below.

The following are the most salient observations made during these experiments. Oxygen in solution increases the adsorptive power of pyrite for calcium

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and for sodium. The effect is greater for calcium than for sodium. The adsorption density of calcium increases with increase in calcium concentration and with pH. Sodium adsorption density increases with pH and decreases with increasing concentrations of calcium and cyanide ions. Calcium adsorption decreases slightly in the presence of sodium and/or cyanide ions. In a solution containing potassium ethyl xanthate more calcium and/or more sodium is adsorbed than in the absence of the collector.

Reagents

Conductivity water was used throughout in the preparation of solutions. It was prepared by redistilling the laboratory supply of distilled water under an atmosphere of purified tank nitrogen. Conductance measurements of the water indicated that it contained less than 0.01 part per million of dissolved salts (expressed in terms of sodium chloride).

Table I. Relation of Calcium Adsorption to Oxygen

Calcium Concentration, Millimols Per Liter	pH		Calcium Adsorption, Micromols Per Sq M	Solutions Exposed To:
	Influent	Effluent		
0.101	9.50	9.49	2.12	Nitrogen
0.101	9.52	7.65	3.93	Atmosphere
0.101	9.50	7.30	4.34	Oxygen
0.145	10.26	10.19	2.39	Nitrogen
0.145	10.30	9.85	7.45	Atmosphere
0.145	10.28	9.05	9.27	Oxygen

Radiocalcium: Radiocalcium was received from the National Laboratory at Oak Ridge, Tenn., as 1½ ml of a chloride solution containing 2 millicuries (mc) of Ca^{45}. This was diluted to 100 ml and stored in a tightly sealed Saftepak bottle. Two to four milliliters of the active solution per adsorption test was found to give the pyrite sample a sufficiently high activity for easy counting in a Q-gas counter. The calcium concentration of the diluted active solution was 8.0 mg per liter.

Radiosodium: The original sample of sodium 22, purchased from the National Laboratory at Oak Ridge, was 1 ml of active solution containing 1 mc as sodium nitrate. The milliliter of active solution was diluted to 1000 ml and stored in a tightly sealed Saftepak bottle. Ten milliliters of the resulting solution were found to give the pyrite sample a sufficiently high activity for easy measurement with a Q-gas counter. The sodium concentration of the active solution was 1.2 mg per liter.

Reagent Gases: Nitrogen and oxygen were received in steel cylinders at 1600-lb pressure and had a listed purity of 99.9 pct and 99.6 pct, respectively. The nitrogen was further purified by passing it over copper gauze at 500°C and finally through a calcium hydroxide bath.

Potassium Ethyl Xanthate: A commercial sample of potassium ethyl xanthate was purified according to Foster.[5] The recrystallized salt was stored in an evacuated pyrex bottle and kept in a refrigerator.

Other Chemicals: Analytical reagent-grade chemicals were used in the preparation of standard solutions of calcium hydroxide, calcium sulphate, sodium hydroxide, sodium cyanide, and hydrochloric acid.

Pyrite

Coarse pyrite handsorted from large crystalline masses was crushed to 28 mesh, then ground in a steel ball mill until all passed through 200 mesh. The ground product was deslimed by sedimentation to eliminate −30 micron particles. The 30/74 micron pyrite was washed several times with dilute hydrochloric acid, then with distilled water, and further deslimed. The cycle was repeated several times and the final product stored in a pyrex flask under dilute hydrochloric acid, pH about 2.5.

A sample of the cleaned pyrite was searched spectrographically for impurities and the following elements were found: Al, Ca, Cu, Na, to the extent of 0.01 pct or less, Ba, K, Si, to the extent of 0.1 to 0.001 pct each.

The krypton gas adsorption apparatus[2, 3] was used to determine the specific surface of the sized pyrite. The average of two measurements gave 612 sq cm per gram. With a surface factor[4] of 2.58 and an average particle size of 52 microns, the calculated specific surface is 590 cm^2 per gram. This is in good agreement with the measured surface area.

An attempt was made to synthesize pyrite containing radioactive isotopes of iron and sulphur, 1—by hydrothermal crystal-growth processes and 2—by irradiating a sample of natural pyrite in the Brookhaven pile for a period of two months. It was anticipated to trace the activities produced by the radioactive constituents in adsorption experiments and thereby help clarify the adsorption mechanism of calcium and sodium on pyrite. The pyrite crystals produced hydrothermally were extremely fine and the yield low, so experimentation along that line was abandoned. The irradiating procedure gave evidence of formation of isotopes other than radioiron and radiosulphur; therefore that method was abandoned also.

Experimental Adsorption Tests

A solution containing reagents such as calcium or sodium hydroxide, hydrochloric acid, calcium sulphate or sodium sulphate, depending on the nature of the test, was passed through a bed of clean, ground pyrite retained on a Buechner fritted-glass funnel. The mineral was then separated from the solution and the amount of reagent on the pyrite surface determined by radioanalysis. All test solutions were exposed to purified nitrogen unless stated otherwise. Details may be found in the thesis by William D. Charles.[6]

Preparation of Ca^{45} and Na^{22} Standards: The relationship between concentration of radionuclide and activity was ascertained by counting several 5-g samples of pyrite onto which was evaporated a measured volume of active solution. The results indicated that the activity of the pyrite sample varied directly with the volume of active solution evaporated on the mineral.

Method of Beta Counting for Adsorbed Calcium and Sodium: Calcium 45 has a half-life of 152 days and emits only β^- radiation. The energy of the beta particle is 0.25 Mev.,[7, 8] the decay scheme being

$$Ca^{45} \xrightarrow[152\ \text{days}]{\beta^-} Sc^{45}$$

This radiation is sufficiently strong to be counted by an end-window type of Geiger-Muller tube, but the counting efficiency is low. Accordingly an internal gas counter was chosen, primarily for its higher efficiency. The counter chamber was operated at atmospheric pressure in a mixture of helium and butane, or Q-gas. The gas was allowed to flow slowly

through the counter to prevent the air from leaking into it.

The same instrument was used to evaluate sodium 22. This isotope has a convenient half-life of 3 years, or long enough to require no allowance for decay during the time taken by the experiment. On decay sodium 22 emits 0.575 Mev. beta radiation and 1.30 Mev. gamma radiation:[7, 8]

$$Na^{22} \xrightarrow[3\ \text{years}]{\beta^-, \gamma} Ne^{22}$$

Five grams of pyrite, or considerably more than enough for infinite thickness, for both beta radiations, was used throughout. Details of evaluation of total cation concentration on the surface of the pyrite may be found in Appendix I to the thesis by William D. Charles.

The activity on a sample of pyrite from the adsorption test was due in part to the cation adsorbed and in part to the cation in the solution retained by the pores of the cake of mineral, before drying. The difference between the total cation determined from activity measurements and the cation in the retained solution gives the amount of cation adsorbed by the pyrite sample. The moisture retained was assumed to have had the same marked cation concentration as the bulk solution. Knowing the specific surface area of the pyrite the result was expressed as micromols of cation adsorbed per square meter of pyrite surface.

Table II. Effect of Sodium on Calcium Adsorption

Calcium Concentration, Millimols Per Liter	pH of Effluent	Sodium Concentration, Millimols Per Liter	Calcium Adsorption, Micromol Per M^2
.10	9.5	0	2.12
.10	9.5	1	2.11
.10	9.5	10	1.60

Adsorption of Calcium on Pyrite

1—Effect of Oxygen in Solution: Preliminary experiments indicated that equilibrium between adsorbed calcium and calcium in solution was not attained when the solutions and the mineral were exposed to the atmosphere. Adsorption tests at concentrations of 0.101 and 0.145 millimols calcium per liter were conducted in which the oxygen content of the solution was varied by exposing the solutions 1—to purified nitrogen, 2—to the atmosphere, and 3—to oxygen.

The data shown in Table I indicate that the amount of calcium which is adsorbed increases with the amount of oxygen in the solution. A change in pH was noted, in the direction of acid formation, and found to be greatest when the solutions were exposed to oxygen.

2—Attainment of Equilibrium: Four adsorption tests were conducted in which the only variable was the time of contact between the solution and the mineral bed. The flow rate was held constant at approximately 500 ml per hr and the tests run for 1, 2, 4, and 6 hr. The experiment was made both under conditions of exposure of solutions to the atmosphere and of exposure to purified nitrogen only.

Where contact was made with air the adsorption increased with reaction time, but with nitrogen, the adsorption was the same regardless of the volume of throughput, thus proving that under non-oxygenated conditions a contact time of 1 hr is sufficient for equilibrium.

3—Effect of pH: Two series of tests were conducted to investigate the effect of pH on calcium adsorption. The calcium concentration in the test solutions was kept constant while the pH was varied with dilute hydrochloric acid. In one series the calcium concentration was maintained at approximately 1.45 millimols per liter while the pH of the solution was varied from 3.95 to 9.95. In the other series the calcium concentration was kept at approximately 0.145 millimol per liter while the pH varied from 3.62 to 9.80.

The results, see Fig. 1, show that the amount of calcium adsorbed increases with pH. A linear relationship between the logarithm of the amount of calcium adsorbed and the pH of the solution is suggested. For a tenfold increase in pH there is approximately a 50 pct increase in adsorbed calcium.

4—Effect of Calcium Concentration: The quantity of calcium ion adsorbed on pyrite at calcium concentrations ranging from 0.25 micromol to 1.8 millimols per liter was measured. The pH varied from 5.4 to 6.8 in spite of the attempt to maintain it at 6.0 with 0.01 N. HCl. Since the variation of calcium adsorption with pH is known, however, it is possible to adjust the calcium adsorption data to a uniform pH, 6.0. The amount of calcium adsorbed as determined in each test was corrected for deviation in pH by using the effect shown in Fig. 1. The corrected values are presented in Fig. 2.

The results indicate a consistent variation in the amount absorbed with calcium concentration in solution. In the concentration range of 0.25 micromol to 20 micromols calcium per liter, the experimental points follow a straight line with a slope of one. The deviations from the straight line appear within experimental error. Beyond a concentration of 20 micromols per liter, the surface concentration increases less rapidly and more complexly.

5—Effect of Sodium: To evaluate the effect of sodium ion on calcium adsorption, tests were made with Na^+ at 1 and 10 millimols per liter, as well as without sodium. The sodium was introduced in the form of sodium chloride. Both the calcium ion and pH of the solution were kept constant with the former at approximately 0.1 millimol per liter and the latter at 9.5. The results are summarized in Table II.

Table III. Effect of Anion Present on Adsorption of Calcium on Pyrite

Anion Present, Millimols Per Liter	Calcium Concentration, Micromols Per Liter	pH of Effluent	Calcium Adsorbed, Micromol per M^2
Blank ($CaCl_2$)	144.	5.30	0.41
.144 Sulphate	144.	5.30	0.36
Blank ($CaCl_2$)	1440.	5.05	1.13
1.44 Sulphate	1440.	5.05	1.20
Blank ($CaCl_2$)	73.2	6.35	0.59
.013 Xanthate	73.0	6.30	1.21
.126 Xanthate	73.1	6.32	1.42
Blank ($CaCl_2$)	145.	9.80	2.90
1.0 Cyanide	145.	9.80	1.97
Blank ($CaCl_2$)	145.	10.30	3.60
10.0 Cyanide	145.	10.30	2.16

The data indicate that the sodium ion present in solution does affect the adsorption of calcium. A slight decrease in the amount of calcium absorbed is found when the sodium ion concentration is increased to 10 millimols per liter.

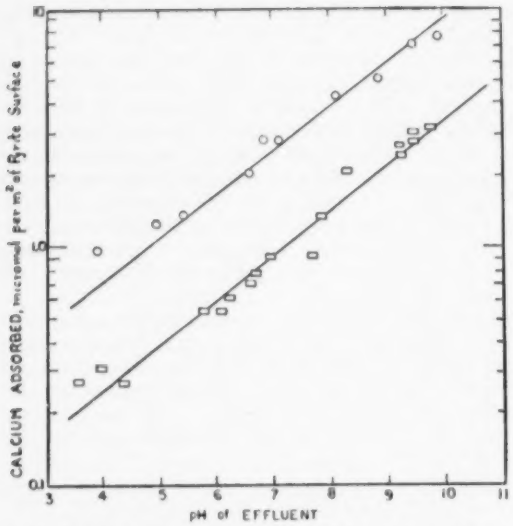

Fig. 1—Effect of pH on calcium adsorption, from solution containing 1.45 millimols of calcium per liter (represented by circles) and 0.145 millimols of calcium per liter (represented by rectangles).)

6—Effect of Variation of the Predominant Anion Present: Several tests were conducted in which the predominant anion other than chloride was varied. Standard solutions of calcium sulphate, potassium ethyl xanthate, and sodium cyanide were added and the adsorption of calcium determined. The results are summarized in Table III.

The data suggest that sulphate ion does not materially affect the adsorption of calcium on pyrite, but that calcium adsorption increases in the presence of xanthate ion and decreases in the presence of cyanide ion.

7—Reversibility of Adsorption: Three tests were conducted to verify the exchange between active and inactive calcium at the surface of pyrite. In each test 1 liter of calcium solution under a nitrogen atmosphere was allowed to pass through a bed containing approximately 7 g of pyrite. The calcium ion concentration, pH, and flow rate were held constant; only the sequence of solution addition was varied.

Table IV. Reversibility Adsorption Tests with Calcium

Solutions Added		pH of Effluent	Activity on 5 G Pyrite, CPM*	Activity of First Test on Pyrite, Pct
Solution 1	Solution 2			
Active		9.20	342.8	100
Inactive	Active	9.20	285.9	83.5
Active	Inactive	9.20	12.4	3.6

* Counts per minute.

In the first test 1 liter of active solution was allowed to pass through the mineral bed and the activity on the pyrite determined. In the second test 1 liter of inactive solution was followed by 1 liter of active solution and the activity on the pyrite determined. In the final test 1 liter of active solution was allowed to pass through the bed, followed by a liter of inactive solution, and the activity remaining on the pyrite was determined.

The data, which is summarized in Table IV, indicate that almost complete exchange takes place when 1 liter of solution is passed through the mineral bed. With sufficient time of contact complete reversibility of adsorption of active and inactive calcium seems likely.

The effect of passing conductivity water through a bed of Ca^{45} —coated pyrite was also investigated. The results of two tests, in which 2 to 4 liters of water were used, are summarized in Table V. The data indicate that with a sufficient amount of conductivity water, complete removal of the adsorbed calcium would occur.

Adsorption of Sodium on Pyrite

1—Effect of Oxygen in Solution: Since it was found that oxygen in solution had a marked effect on calcium adsorption, a series of tests were conducted to evaluate the effect of oxygen, if any, on sodium adsorption.

Adsorption tests at concentrations of 1 and 0.1 millimol sodium per liter were made, in which the oxygen content of the solution was varied by exposing the solutions 1—to purified nitrogen, 2—to the atmosphere, and 3—to oxygen.

The data, see Table VI, indicate that the amount of sodium adsorbed increases with the amount of oxygen in solution; however, this effect is not nearly as great as in the case of calcium when the solution contained disolved oxygen.

2—Attainment of Equilibrium: Four adsorption tests were conducted in which only the time of contact between the solution and the mineral bed

Table V. Leachability of Adsorbed Calcium

Ca Concentration in Activating Liquor, Micromols Per Liter	Cond. Water Used, Vol.	pH of Effluent	Activity on 5 G Pyrite CPM	Activity of First Test on Pyrite, Pct
0.6		6.1	2445	100
0.6	2 liters	6.0	90.7	3.7
0.6	4 liters	6.0	55.0	2.3

was varied. The sodium concentration, pH, and flow rate (~500 ml per hr) were held constant. The solutions were exposed to purified nitrogen and the tests run for 1.0, 1.5, 2.0, and 4.25 hr. The data indicate that a contact time of 1 hr is sufficient for equilibrium to be reached between adsorbed sodium and sodium in solution. There was substantially no change in the pH of the solution passing through the pyrite bed.

3—Effect of pH: A series of tests was conducted to investigate the effect of pH on sodium adsorption. The sodium concentration in the test solutions was kept constant at approximately 0.101 millimol per liter while the pH was varied with dilute hydrochloric acid. The results obtained are shown in Fig. 3. A linear relationship between the logarithm of the amount of sodium adsorbed and the pH of the solution is suggested. For a tenfold decrease in hydrogen ion concentration there is approximately a 40-pct increase in adsorbed sodium.

4—Effect of Calcium: To evaluate the effect of calcium ion on sodium adsorption, tests were made with calcium at 1 and 10 millimols per liter, as well as without calcium. The calcium was introduced in the form of unmarked calcium chloride. Both the

sodium ion and pH of the solution were kept constant, with the former at approximately 0.10 millimol per liter and the latter at 10.8.

The results, given in Table VII, indicate that calcium ion has a very marked effect on the adsorption of sodium by pyrite. The amount of sodium adsorbed decreases rapidly with increasing calcium concentration.

5—Effect of Variation in the Predominant Anion Present: Several tests were conducted in which the predominant anion other than chloride was varied. Gaged amounts of sodium sulphate, sodium cyanide, and potassium ethyl xanthate were added and the adsorption of sodium determined. The results obtained are summarized in Table VIII.

The data indicate that the adsorption of sodium is not materially affected by the sulphate ion present in solution. However, it was found that the adsorption density of sodium increases in the presence of xanthate ion and decreases in the presence of cyanide ion. Qualitatively, the results are parallel to those obtained with calcium.

Table VI. Effect of Oxygen on Sodium Adsorption on Pyrite

Sodium Concentration, Millimols Per Liter	pH		Sodium Adsorption, Micromols Per M²	Solutions Exposed to:
	Influent	Effluent		
0.10	8.05	8.02	.086	Nitrogen
0.10	8.02	7.50	.112	Atmosphere
0.10	8.03	7.20	.115	Oxygen
1.0	10.28	10.27	2.14	Nitrogen
1.0	10.28	10.25	2.34	Atmosphere
1.0	10.28	10.20	2.66	Oxygen

Discussion of Results

Our experiments[6] have shown that oxygen in solution increases the adsorption of calcium and/or of sodium by pyrite. The non-equilibrium condition which exists when the solutions are open to the atmosphere seems due to the constant alteration of the mineral surface by dissolved oxygen, viz., the continuous formation of oxides of sulphur and perhaps of iron at the pyrite surface. The pH of the effluent from the adsorption column is lower than that of the influent when the solution contains dissolved oxygen but is unchanged when oxygen is excluded. This is probably because of dissolution of the oxy-acids of sulphur that form on oxidation

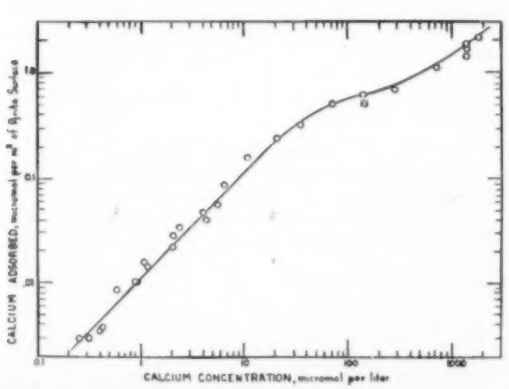

Fig. 2—Effect of calcium concentration on the adsorption of calcium on pyrite. Corrected to pH = 6.0.

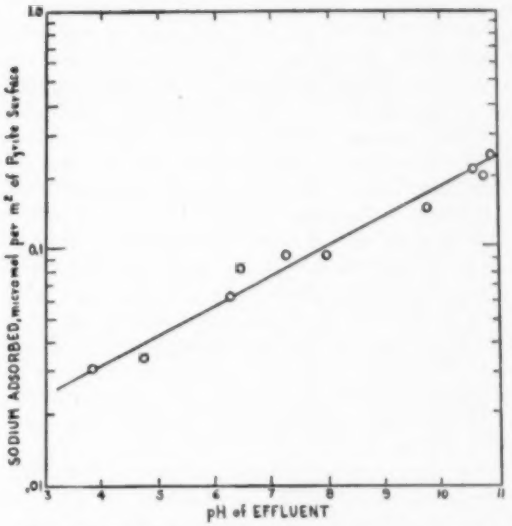

Fig. 3—Effect of pH on sodium adsorption, from a solution containing 0.101 millimols of sodium per liter.

of the mineral. The effect of dissolved oxygen was greater on calcium adsorption than on sodium adsorption. This is in line with what is known of the solubilities of calcium sulphate and sodium sulphate. It would certainly be enlightening at this point had it been possible to compare the effect of dissolved oxygen on the adsorption of a cation having a sulphate less soluble than calcium, e.g., strontium, barium, or radium. Unfortunately, time was not available to explore this suggestion.

Since the dimensions of the pyrite crystal lattice are available,[11] it is possible to calculate the per cent coverage by adsorbed cations from the surface-area determination (612 cm^2/g). The requirements for a complete monolayer is assumed to be one cation per pair of sulphur atoms or per iron atom. Assuming that the surface of crushed pyrite consists of an assortment of 100 planes, and on the basis of the accepted lattice, the area per site is found to be 14.5 A^2. This calculation yields 11.4 micromols per sq m for a complete monolayer. Therefore the surface covered, at the highest concentration of calcium, 1.8 millimols per liter, is approximately 18 pct. At a concentration of 0.1 millimol per liter and a pH of 6.0 the comparative amounts of surface coverage for calcium and sodium on pyrite is found to be 4.5 and 0.35 pct, respectively. There was no experimental evidence, within the limits of this investigation, to indicate that a sufficient amount of cation was ever adsorbed to form a complete monolayer.

The results of surface-covered calculations are quite different, however, if the cations are assumed

Table VII. Effect of Calcium on Sodium Adsorption on Pyrite

Sodium Concentration, Millimols Per Liter	pH of Effluent	Calcium Concentration, Millimols Per Liter	Sodium Adsorbed, Micramols Per Sq M
0.10	10.8	0	0.198
0.10	10.8	1	0.040
0.10	10.8	10	0.027

to be adsorbed as hydrated ion. The cations are known to exist in aqueous solution in highly hydrated forms; therefore their adsorption as such may be the governing factor when their configuration on the pyrite surface is considered. The radii of the hydrated cations reported in the literature vary; Nachod and Wood[12] give 6.7 A for calcium and 7.8 A for sodium. When these figures are used, the amount of calcium or sodium required to form a complete monolayer of densely packed hydrated ions is 1.2 and 0.9 micromols per sq m, respectively. At a concentration of 0.1 millimol per liter and a pH of 6.0, the comparative amounts of surface coverage, hydrated cation basis, on pyrite are 40 pct for calcium adsorption and 4.0 pct for sodium. Also, the amount of calcium adsorbed at an equilibrium concentration of 0.64 millimol per liter is sufficient to form a complete monolayer of the hydrated ions.

The adsorption of calcium, as illustrated in Fig. 2, increases linearly with concentration up to a point where the curve begins to level off, and then appears to increase again approaching a slope of unity. Such a change in slope would seem to indicate that the character of the substratum on which calcium is adsorbed had changed. This is possibly the case, for the curve begins to deviate from the linear relationship as it approaches the point corresponding to a monolayer of densely packed hydrated calcium ions.

In the concentration range of 0.12 to 20 micromols of calcium per liter the equation of the adsorption curve, Fig. 2, may be expressed as follows:

$$\Gamma = k\,C$$

where Γ is the amount of calcium adsorbed per unit surface, C the equilibrium concentration of calcium in solution, and k a constant. This is the Langmuir adsorption equation where in very dilute solutions or at small surface coverage the adsorption density is directly proportional to the concentration in solution. At high concentrations the adsorption of an electrolyte cannot be expressed by such a simple relationship.[10] The electrical effects produced at the interface by ionic adsorption then become important. It is quite possible that the deviation of the experimental curve from a slope of unity at concentrations greater than 20 micromols of calcium per liter may be rationalized in that fashion.

Table VIII. Effect of Anion Present on Adsorption of Sodium on Pyrite

Anion Present, Millimols Per Liter	Sodium Concentration, Millimols Per Liter	pH of Effluent	Sodium Adsorbed, Micromols per M^2
Blank (NaCl)	0.10	6.3	0.081
0.05 Sulphate	0.10	6.3	0.084
Blank (NaCl)	1.0	6.0	0.56
0.505 Sulphate	1.0	6.0	0.54
Blank (NaCl)	0.10	9.0	0.125
0.069 Xanthate	0.10	9.0	0.130
0.126 Xanthate	0.10	9.0	0.243
Blank (NaCl)	0.10	10.5	0.201
0.051 Cyanide	0.10	10.5	0.131
Blank (NaCl)	1.0	10.3	2.15
0.90 Cyanide	1.0	10.3	1.71

Variation in the concentration of hydrogen ion affects slightly the adsorption of calcium and sodium, see Figs. 1 and 3. The experimental curves indicate a surprisingly small effect which may be expressed as follows:

$$\log \Gamma x = \log \Gamma_7 + n\,(x - 7)$$

in which n is the slope of the line, Γ_7 is the adsorption at pH 7, and Γx the adsorption at pH = x. In the results, n is equal to about 1/6 for the calcium adsorption data and about 1/8 for the sodium data. A similar relationship exists for the variation of barium[9] and sodium[10] adsorption on quartz with variation in hydrogen ion concentration, n being equal to about 1/5 for the barium adsorption data and about 1/6 for the sodium data.

The fact that calcium and sodium ions affect one another in their adsorption on pyrite indicates competition between the cations for the same sites. Experimental evidence has shown that calcium adsorption is less affected by sodium ions than is sodium adsorption by calcium ions. The more pronounced affinity of calcium for the pyrite surface is further justified by the fact that calcium adsorption is greater than sodium adsorption at the same concentration and pH.

Acknowledgment

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The Selection of Detachable Drill Bits

by E. R. Borcherdt

IT is notable that the first large-scale mine operation equipped entirely with detachable bits was the Badger State mine of the Anaconda Copper Mining Co. in Butte, Montana, just 30 years ago. This mine in 1922 was producing approximately 1200 tons of ore per day. Much of the data presented in C. L. Berrien's article[1] describing the development and installation of the Hawkesworth detachable drill bit were obtained from these operations.

As in any pioneering effort, no precedent existed and many difficult problems required solution, so that the changeover to detachable bits at all Butte hill mines was not completed for 6 years. There was widespread disbelief as to the probable efficiency of the new installation.

Some attempts were made in 1931 by the owners of the Hawkesworth patents to interest Ontario gold mine operators in the bit. These efforts were not successful, but they undoubtedly stimulated thinking which resulted in the invention and patenting of several well-known Canadian detachable bits, one of which is now a widely used throwaway bit. The success of the Butte installation also led to the development of the threaded type of bit connections by several well-known manufacturers, and in 1935 these bits were introduced to the mining industry on a national scale.

The original Hawkesworth bit was not provided with a water hole but depended upon water passing through the clearance opening between the tongue in the bit and the groove in the rod to flush cuttings from the drill hole, see Fig. 1. In December 1935 it was found that this method of introducing drilling water to the bit face resulted in high dust counts. To correct this a water hole was drilled on the central axis of the bit, passing through the tongue. Unfortunately, quenching water would rise through the small water hole, spot-hardening the tongue to cause breakage, never completely eliminated.

In the fall of 1936 large-scale tests indicated that savings would be effected by use of a threaded type of bit, which was therefore adopted as standard for all Butte mines. This type of bit was used until 1947, when it was superseded by a one-use slip-on type.

Since the first use of the Hawkesworth bit every detachable bit of importance has been investigated, and where advantages which might reduce costs or increase efficiency were indicated, substantial tests of the bit were carried on in the Butte mines. When tests demonstrated the advisability of changing from one kind of detachable bit to another the change was made at one level or in one area each day until the new rod and bit equipment was used throughout the mine. This involved a minimum of cost and disruption of drilling.

Intelligent selection of a detachable bit to obtain optimum results requires careful consideration to achieve a balance between the three principal types of equipment used in the drilling process: 1—drill bits, 2—drill steel, and 3—drilling machines. Optimum results imply maximum output and minimum cost per unit of output. Since every rock type differs in drillability and it is generally impractical to provide equipment for more than one or two types of rock which may occur in one operation, selection of equipment must encompass average drilling conditions. However, on exceptional occasions several widely differing conditions may make it mandatory to provide equipment best suited to each condition.

The choice of rock-drilling equipment is a most controversial subject and one that is further complicated by unreliable and frequently misleading performance claims. Small operators without the means for making accurate evaluations of equipment frequently suffer from these over-enthusiastic claims.

It is apparent from experience in rock drilling throughout the world that rock drillability is not alike in any two places, and that selection of proper equipment can only be made after conducting thorough trials of various types of equipment.

Some recent drilling tests in tactite and hornstone at the Darwin, California mine of the Anaconda Co. present some interesting clues on rock drillability. Microscopic examination of thin sections of these rocks reveals that mineral composition and rock texture are equally important in governing drillability. The Darwin hornstone is at times so abrasive that the carbide bit cutting edges become flattened to 3/32 in. in 2 to 4 ft of drilling, and some carbide bits were dulled to this point after 9 to 10 in. of drilling. This wear was determined to be the proper point for resharpening to eliminate carbide insert breakage or breakage of the steel rod when drilling with 1½ to 1⅜-in. bits, with a drifter of 2¾-in. diam and 90 to 100 psi air pressure, see Supplement A.

Before considering the merits of various bit designs it may be well to review the mechanics of drilling rock with percussion drills. A sharp bit cuts by penetration and chipping. The amount of penetration governs the amount of chipping and depends upon the contact area of the cutting edge, the foot-

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pound blow of the drill hammer, and the penetrability of the rock in terms of hardness and toughness. This in turn is dependent upon the texture and mineralogical composition of the rock. A simple illustration may serve to explain the relationship between contact area of the bit and the foot-pound blow for maximum penetration. A fine pointed tack will readily penetrate a piece of hard oak with one blow of a light tack hammer, but if a 60-penny spike is substituted for the tack, no matter how hard the spike is struck with the tack hammer it will not penetrate the oak. However, if a single jack is substituted for the tack hammer, a sharp blow will cause the 60-penny spike to penetrate the oak readily. So it is with a bit that the area or length of the cutting edge is one of the factors determining degree of penetration in a given rock, and so it is that the larger the area or length of cutting edge the greater the resistance to penetration and the larger the foot-pound blow or the heavier the rock drill hammer required for penetration in a given rock. Fig. 2 illustrates the sequence of penetration and chipping performed by the cutting edge of a bit. As the cutting edges advance through a given arc in succeeding hammer blows of the drill, the material between the indentations *a* and *c* forming the segment of a circle is detached from the rock mass by shearing or chipping. The size of segment chipped is governed by the lead of the rifle bar and is entirely dependent upon the brittleness or toughness of the rock and its hardness or penetrability. In tough rock it may not be possible to chip the segment *a-c*, in which event it would be necessary to reduce the rotation lead to point *b* to accomplish chipping of a smaller segment, *a-b*. The larger the segment chipped the larger the resultant cuttings will be, within clearance limits of the bit, and the faster and more efficient the drilling process becomes. Resistance to penetration can be altered by lessening the angle of the cutting edges or by decreasing the contact area of the total length of the cutting edge or edges. In a rose bit this length will obviously be maximum, and in a single chisel bit it will be minimum for a given gage. However, the total cutting edge length of a standard cross bit may be reduced by removal of the center portion of the cutting edge which normally does little work. To illustrate this, see Fig. 2, a plan view of a 1½-in. drill hole is divided into three circle areas, the radii of which increase by ¼-in. intervals. The area of the central circle is 0.19635 sq in. The No. 2 area is 0.58905 sq in., and the No. 3 or outer circle 0.98175 sq in. This shows that the middle or No. 2 area requires three times as much work on the part of the bit as the central

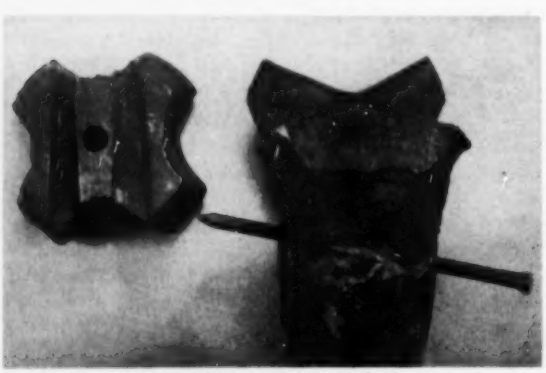


Fig. 1—Hawksworth bit and shank.

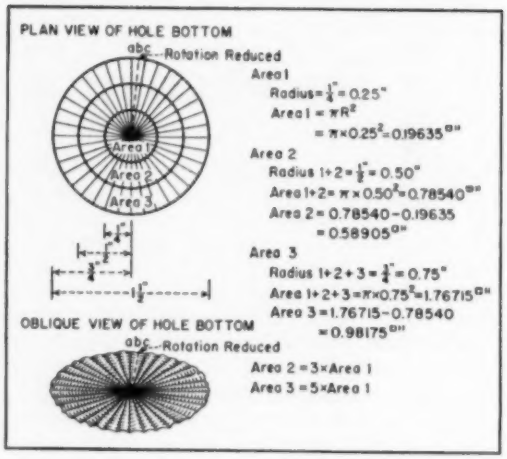

PLAN VIEW OF HOLE BOTTOM
abc—Rotation Reduced
Area 1
Area 2
Area 3
Area 1
Radius = 1/4" = 0.25"
Area 1 = πR²
= π×0.25² = 0.19635 sq in
Area 2
Radius 1+2 = 1/2" = 0.50"
Area 1+2 = π×0.50² = 0.78540 sq in
Area 2 = 0.78540 − 0.19635
= 0.58905 sq in
Area 3
Radius 1+2+3 = 3/4" = 0.75"
Area 1+2+3 = π×0.75² = 1.76715 sq in
Area 3 = 1.76715 − 0.78540
= 0.98175 sq in
OBLIQUE VIEW OF HOLE BOTTOM
abc—Rotation Reduced
Area 2 = 3×Area 1
Area 3 = 5×Area 1

Fig. 2—Theoretical drilling impression with crossbit.

area, No. 1, and that the outside area, No. 3, requires five times the work that is required of the bit to excavate the central portion. Thus it is obvious that the ends of the cutting edges take the brunt of the wear on the bit, and in abrasive types of rock this wear may be supplemented by additional abrasion of the gage surfaces from rotation of the bit.

Usually a bit must be discarded when its cutting edges are flattened by abrasion to the point where penetration and resultant chipping cease and bit penetration is entirely by crushing, or, when the gage surface becomes worn to a reverse taper and the bit binds in the hole, see Fig. 3. The proper discard point will vary with the physical characteristics of the rock drilled. During the cutting and chipping period with sharp cutting edges the cuttings are coarse and the energy transmitted to the drill bit by the drill hammer is absorbed in penetrating and cutting the rock. However, when the cutting edges become excessively flattened, penetration is decreased, the cuttings become very fine, and a great deal of the energy of the drill hammer is dissipated in heat, which in tough drilling rocks notably increases the temperature of the drilling water issuing from the hole. At this point the advance of the bit is largely by crushing. The low penetration resulting from blunted cutting edges sets up excessive vibration in the steel rod, causing early breakage of the drill rod. Whether drilling is done with a carbide insert rod, a carbide insert detachable bit, or a detachable steel bit, continued drilling with excessively flat cutting edges in hard, tough drilling rock will result in one of four types of failure: 1—breakage of carbide insert, 2—breakage of the detachable bit skirt, 3—failure of the connection, or 4—breakage of the drill rod, see Figs. 4-9.

There are of course types of rock in which the cutting edges are scoured or hollow-ground and become sharper with continued drilling. Other types of rock yield no over-drilling, and gage wear and binding occur before the cutting edge is dulled, see Fig. 10.

Dulling of the bit is progressive, and is evidenced by reduction in drilling speed. Whether this reduction is abrupt or gradual depends upon the rock drilled and the bit design. The fact that the average drilling speed of a carbide bit is much higher than that of a steel bit in many types of difficult drilling

Fig. 3—Dulled bit showing reverse taper and flattened cutting edges.

ground is attributable to the greater resistance of the carbide bit to dulling. The steel bit will drill exactly as fast, in some cases faster, in the first few seconds of use, but its speed drops off rapidly as wear of the cutting and gage surfaces takes place. In medium or soft ground this advantage in increased drilling speed over the steel bit is not apparent. The high resistance to dulling shown by carbide inserts results from the inherent high wear resistance of the cemented carbide, which possesses a combination of high scratch resistance and high indenting resistance. Hardness of commercial carbides are in the range of 85 to 93 Rockwell A Scale, whereas steel bits range in hardness from 62 to 66 Rockwell C Scale. A reading of 65 C Scale is equivalent to a reading of 83.9 A Scale.

With few exceptions, basic bit designs have changed very little, and the relative merits of various bit designs have been well evaluated in various types of rocks during the past 40 years. A standard cross bit with and without variations is by far the most popular bit used in the world today. Variations consist of wide or narrow wings, cutting edge angles from 90 to 120°, large center hole, undercut wings, exaggerated clearance grooves for cuttings, and special adaptations embodying pilot cutting faces. The proper cutting edge angle depends upon the friability of the rock drilled. Too large an angle results in lowered penetration and hence sets up excessive rebound of the steel. Large cutting edge angles increase the gage surface, desirable in abrasive and friable rock. Large gage surfaces are obtained by widening the bit wing in addition to increasing the cutting edge angle. Where maximum penetration is desirable in very friable rocks and gage wear is minimum, a narrow wing is advantageous.

Even the position of the water hole influences drilling speed, as in some types of hard ground a change from side to center hole resulted in a decided increase in drilling speed. In types of ground where plugging of bits and rods is a problem, a side hole bit is helpful, see Fig. 4 and Table I.

In some types of rock it is desirable to use an undercut wing in which only the upper part of the gage surface is fully hardened; the remainder, being softer, gives strength and backing to the wing, and being soft wears at the same rate as the smaller hardened surface. Thus the bit loses gage without the usual reverse taper and consequent binding.

The cross bit has been applied successfully in nearly every type of rock. But if provision for clearance and removal of cuttings is insufficient, especially in small detachable bits, and in very friable rocks that are rapidly cut, a chisel bit may be superior because it has the advantage of excellent cuttings clearance. This feature is particularly valuable in drilling down holes. The present popularity of the chisel bit has been enhanced by its use with Swedish insert rods. The adoption of this type of bit was perhaps influenced by the fact that it could be readily and accurately resharpened and the fact that a single cutting edge requires a minimum of car-

Table I. Results of Bit Tests in Clay-Rich Butte Rock

Center Hole Bits	Statistics	Center and Side Hole Bits	Statistics	Side Hole Bits	Statistics
Footage drilled	446	Footage drilled	1526	Footage drilled	664
No. of steel plugged	16	No. of steel plugged	30	No. of steel plugged	6
Footage drilled per plug	27.9	Footage drilled per plug	50.9	Footage drilled per plug	110.7

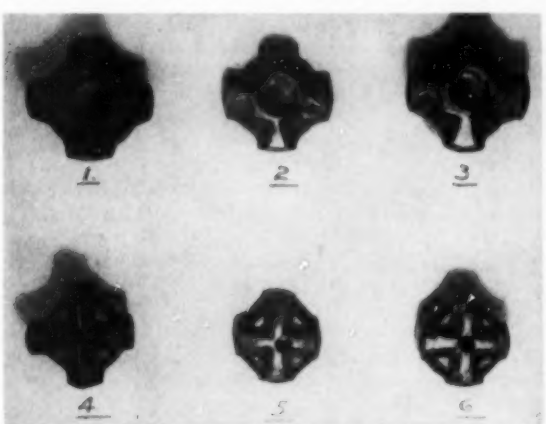


Fig. 4—(1) Sharp 2L Liddicoat bit. (2) Dulled 2L Liddicoat bit. (3) Excessively dulled 2L Liddicoat bit. (4) Sharp 1D Liddicoat bit. (5) Dulled 1D Liddicoat bit. (6) Dulled 1D Liddicoat bit.

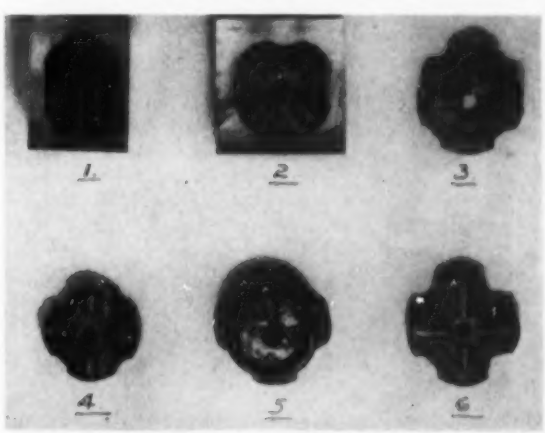


Fig. 5—(1) Coromant insert broken by excessive dulling. (2) Excessively dulled Timken bit with broken skirt. (3) Excessively dulled Liddicoat carbide bit, insert failure. (4) Excessively dulled Liddicoat carbide bit, broken skirt. (5) Excessively dulled Liddicoat 2L bit, rod tip broken. (6) Timken bit at permissible dullness.

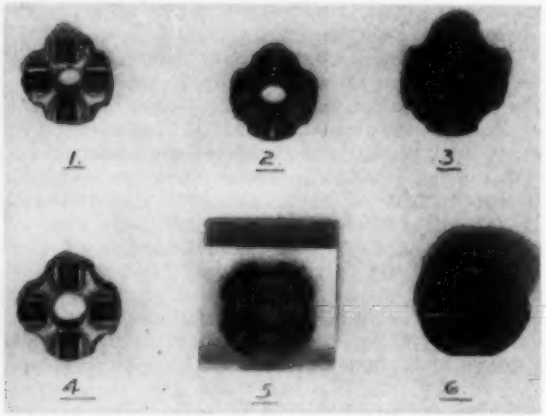


Fig. 6—(1) New Liddicoat bit face, experimental. (2) Same bit at permissible dullness. (3) Timken bit at permissible dullness. (4) New Liddicoat bit face, experimental. (5) Same bit at permissible dullness. (6) Kennametal bit at permissible dullness.

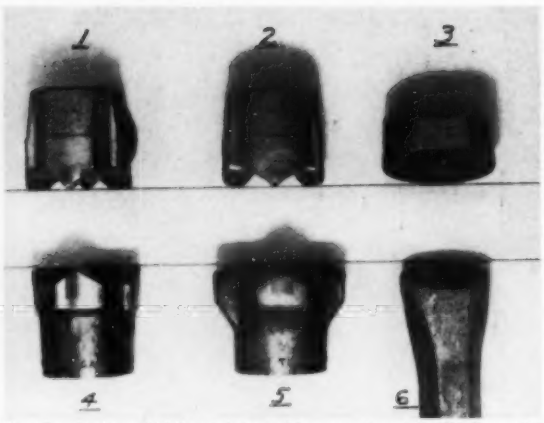


Fig. 7—(1) New Liddicoat bit profile, experimental. (2) Same bit in profile showing reduction of carbide. (3) Kennametal chesel bit showing crown and reduction of carbide on outer edges at permissible dullness. (4) New Timken bit in profile. (5) Similar bit in profile showing reduction in carbide at permissible dullness. (6) Dulled Coromant insert.

bide. The chisel bit is well adapted to uniform ground but in vuggy and broken ground it is not so efficient as the cross bit. Experiments are now under way which give promise of substantial increases in drilling speed with a re-designed chisel bit.

Both chisel and cross-type bits are available in detachable steel bits, detachable carbide insert bits, and carbide insert steel. Threaded-type detachable multi-use steel bits and carbide insert bits are supplied by two American manufacturers. The exact and uniform hardening of single-use bits is undoubtedly the major reason for the increasing popularity of the slip-on bit. With these bits it is almost unheard of to encounter hardening failures characteristic of soft bits, whereas with multi-use types, soft bits were frequent even where large-scale electrically heated salt pots were provided for heating. Apparently operators have become unwilling to place responsibility for proper hardening of bits in the hands of temperamental and frequently itinerant blacksmiths.

Detachable steel bits of the single-use slip-on type

Fig. 8—Ingersoll Rand Carset bit excessively dulled, resulting in braze failure.

are available from several manufacturers, one of whom will shortly place on the market a slip-on type of carbide insert bit.

Insert steel is obtainable from several American manufacturers and one Swedish importer. The choice between carbide insert steel and carbide detachable bits is one that should be determined by actual test of each type to evaluate the advantages and disadvantages of each. Damage to the carbide of an insert steel results in the loss of a $19 to $20 rod, whereas damage to the carbide in a detachable bit results in loss of the bit only, amounting to $7 to $14 for small bits. Also the matter of transportation for resharpening a rod or a single bit is a subject for investigation. The manufacturers of insert steel claim the advantage of smaller bit sizes without reduced clearance, whereas the threaded insert bit requires additional skirt thickness which detracts from its clearance. It is claimed also that the life of a threaded connection is shorter than that of the carbide inserts or the steel rod. Recent tests indicate that a new slip-on type of carbide insert bit used with alloy steel rods overcomes both these objections.

As to the relative merits of carbide insert bits and steel bits, it is widely agreed that in hard, tough abrasive rock, carbide generally has a distinct economic advantage. However, there are exceptions to the rule. In some extremely hard and friable rocks it has been found impossible to drill with carbide insert bits at a reasonable cost, yet these can be drilled with single use steel bits at reasonable cost.[2] And there are no doubt exceptional circumstances in which carbide would have advantages over steel bits in soft ground.

A rule gaining popularity in Canada, to which of course there are exceptions, is that carbide bits are not necessary where drilling speeds of 10 in. per min and over are obtainable with steel bits.

Results of large-scale tests of carbide insert detachable bits and carbide insert steel conducted at the Sullivan mine of the Consolidated Mining and Smelting Co. of Canada, Ltd. were presented at the Annual Western Meeting of the Canadian Institute of Mining and Metallurgy, November 1950, by J. W. Reynolds. These results are believed to be of sufficient interest to be quoted verbatum.

"As a result of controlled and operational tests,

plus the experience gained from the use of tungsten carbide for all chert drilling for a period of over two years, certain conclusions may be drawn.

"1—Performance with carbide bits exceeds that with steel bits in hard ground and is about the same in medium ground and in soft ground so far as penetration speeds and rate of advance are concerned.

"2—The cost of drilling with carbide bits is definitely lower than with steel bits in hard ground, is about the same in medium ground, and is higher in soft ground. The higher cost in soft ground is mainly attributable to the fact that by comparison with their respective bits the carbide bit connection is greatly inferior to the carbide bit while the steel bit connection is superior to the steel bit. As a result so much of the potential of the carbide bit is wasted in soft ground through discard, before the carbide is finished, that the steel bit is more economical. Tungsten carbide has not yet been supplied in the universally accepted bit for use in all rock types.

"3—The undesirability of supplying large quantities of tipped rods has hindered adoption of inserted rods in place of bits in hard ground, especially since attachment failure is such a negligible factor there. The use of tipped rods for drilling in soft ground may be advantageous and is being investigated.

"4—Achieving the best performance from tungsten carbide bits has required changes in rock drills to those with fast rotation and pneumatic feed.

"5—Obtaining the best performance from carbide bits requires best obtainable drill rod performance. Alloy steels are required but their use involves rigid standards of shop practice.

"6—Successful employment of carbide bits is dependent greatly on detailed education, strict supervision, and rigid control both with distribution and use."

At other Canadian mines carbide bits improved drilling operations, but at a cost greater than was compensated for by the reduction in man hours of labor.[3]

The inherent strength of cemented tungsten carbide is limited; it has been proved to have sufficient strength for percussion drilling within limits, but certain measures must be taken to obtain satisfactory results. One mine lists the following precautions to be observed with the use of threaded carbide insert detachable bits.[4]

1—Insistence on the tightening of bits on rods by Stilson wrenches after each use.

Fig. 9—Tungsten carbide cutting edge at maximum permissible dullness. X30.

Fig. 10—Dulled bit showing reverse taper and sharpened cutting edges.

2—Instruction that the machine should not be turned on until the bit is tight against the bottom of the hole when changing to longer lengths.

3—Orders that bits be returned for reconditioning when 3/32-in. wear shows on the cutting edge.

4—The use of .005-in. undersize ring gage which is issued to the miner to control rod discard.

5—The use of ring gages by shift bosses to double-check the miners' rods at least once a day.

It has been found that drill steel life is governed directly by bit size; the larger the bit the less footage drilled before steel fails from fatigue, see Fig. 11. It has long been known that drilling speed increases inversely as the square of the diameter of the hole. For both these reasons it is desirable to use a small starting bit which will result in the minimum-size hole bottom consistent with satisfactory breaking. In hard abrasive rock the use of a steel bit requires larger starter sizes than with carbide bits and a greater number of steel changes, whereas the hole can be bottomed with one or two very small gage change carbide bits so that for all practical purposes the hole is the same diameter from top to bottom. The fact that it can drill a small hole quickly in hard abrasive rock is one of the major advantages of the carbide bit. The decision to use carbide or steel bits is governed entirely by cost comparisons derived from careful tests in all the various drilling conditions encountered.

Drill steel sizes vary from ⅞-in. hexagon and quarter-octagon to 1½-in. hollow round, from ⅞-in. to 1¼-in. steel ordinarily being used in underground mining operations. In general the larger the bit size the larger the steel section required, and the larger the steel section the heavier the individual rod. Where underground transportation is involved, weight is an important consideration. Also, the heavier drill steel requires a larger foot-pound blow and a heavier rock drill. Consideration must also be given to the fact that the larger the section the smaller the number of rods which can be made up from a ton of steel, see Fig. 12.

Until the development of satisfactory alloy hollow drill steel, use of the ⅞-in. section was not entirely satisfactory. Carbon steel in this size lacked stiffness and became excessively bent and kinked from rough handling underground. Furthermore, its limberness in long lengths caused it to absorb sufficient energy

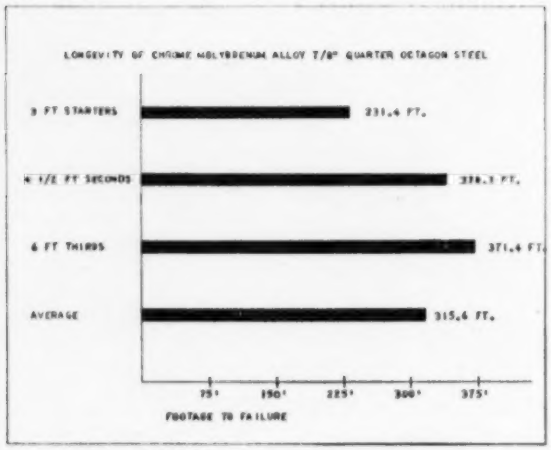


Fig. 11—Rod breakage, a factor of bit size.

of the hammer blow to result in a substantial drop in drilling speed. This condition was corrected experimentally by *skin hardening*. Alloy steel rods possess greater stiffness and have eliminated this trouble, so that the ⅞-in. quarter-octagon section with slip-on bits makes small-hole drilling feasible.

Employment of round and hexagon steel sections requires that lugs or collars be forged, and this forging and subsequent heat treatment set up strains in the rods which result in ultimate failure. In Africa, for this reason, rubber and steel collars are used. Quarter-octagon steel is generally used in anvil block-type drills requiring straight shanks with no collars or lugs.

Again, choice of steel section is dependent upon rock conditions. The use of shankless quarter-octagon rods is general with stoper drills but its use in drifters might be impractical in soft, vuggy, or ravelly ground in which bits and steel are removed from the hole with some difficulty. However, if miners become accustomed to its use most types of rock can be drilled satisfactorily with drifters using quarter-octagon steel.

In stoper drilling employment of ⅞-in. quarter-octagon steel is particularly advantageous as compared to 1-in. quarter-octagon, since because of its reduced weight it is possible for a miner changing steel to hold the drill in one hand and grasp and place a long steel in the bottom of the hole with the other hand. The weight of long 1-in. quarter-octagon rods does not permit this practice, so it becomes necessary to stand the drill against timber or a wall or lay it down while long steel changes are made.

A new development opening up an entirely new range of possibilities in drilling practice is the use of high carbon chrome molybdenum alloy hollow drill steel in the as-rolled condition, that is, in the unhardened condition as received in bar lengths from the mill. The rods are cut into proper lengths from bar stock with abrasive cutoff wheels. Chuck ends are then champfered on a grinding wheel and the slip-on connections are formed with a special grinder. This practice eliminates strains set up in the steel by heat treating, thus assuring maximum steel life. The consequent elimination of heat-treating equipment results in greatly reduced rod-preparation costs. Exhaustive tests of these rods with steel bits showed an increase of about five to six times the rod life, see Fig. 13, of straight carbon hollow drill steel. The use of these rods with carbide insert bits of the slip-on type should prove a most interesting combination, especially in view of the fact that a 1¼-in. diam bit may be used, which is somewhat smaller than usual in bottoming of holes used for breaking, except in boulder plugging. Some mines bottom holes at 1⅜-in. diam, but average American practice seems to be between 1½ and 1⅝ in.

The third factor influencing bit selection is the drilling machine, which again is determined by average rock conditions. In tough abrasive rock the strong rotation of a large bore drill to permit making a full gage change or the necessity for the great penetrating power of a heavy drill may be a determining factor. Where extreme variations in rock conditions exist it is usual to provide drills best suited to each type of rock. Experiments with drills of various bores and perhaps various rotation speeds are the only satisfactory means of determining the most efficient rock drill, bit type, and drill steel combination. In general, where rock is abrasive and gage wear is a problem, a slow rotation is helpful, but in rock which overdrills and is not particularly abrasive a fast rotation may increase the drilling speed materially. It should be pointed out that the maintenance costs of heavy drills are higher than those of light drills; therefore it is not good practice to select drills larger than required. The need is for sufficient drilling speed to permit drilling the holes required to break a round for a maximum cycle. For example, it would be uneconomical to choose a heavy fast drill with which 10-ft rounds can readily be drilled and broken, when the breaking of an 8-ft round supplies the maximum amount of broken material that can be handled on cycle. The increased weight of heavy equipment is also a factor for consideration. The trend is towards small bits, both steel and carbide, and lighter drills. However, in tunnel contracts where extreme speed of advance is essential and the use of jibs and jumbos makes weight less important, the opposite is true and the trend is perhaps towards heavier drills with larger bits.

Because of the limited inherent strength of cemented tungsten carbide, especially when it is used with small gage bits, where unit impact stresses are high, the foot-pound blow must be kept within safe limits to prevent undue fracturing of the carbide, and smaller bore, lighter drills are indicated.

In extremely difficult drilling conditions where small carbide bits are necessary a 2½-in. to 2¾-in. drill is very satisfactory. Larger drills may be used with larger bits having larger and heavier carbide

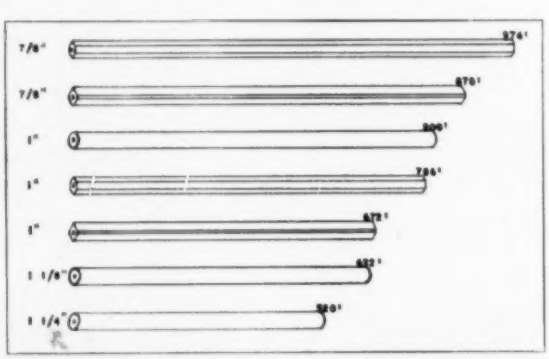


Fig. 12—Footage of drill rods that can be fabricated from a ton of steel.

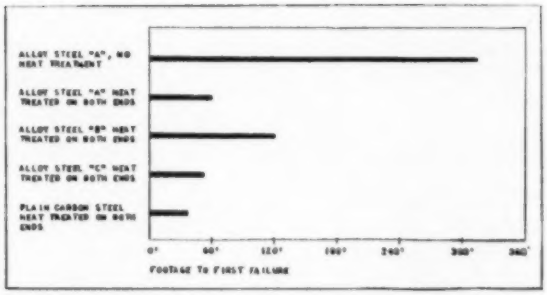


Fig. 13—Chrome molybdenum vs carbon steel rod life.

inserts. However, the large bit drills more slowly than the small one; therefore the choice of drill bit size and rock drill size for optimum drilling results depends upon trial in the particular rock in question. Long-hole drilling in hard ground to which carbide bits are particularly well adapted requires larger drills and hence larger bits.

A small jackhammer mounted on a pushfeed is a versatile piece of equipment, costing about $550. It is a one-man machine and drills small horizontal holes with ease, provided that they are not too high; hence the outfit is particularly well suited to slashing or enlarging. Again it is necessary to make comparative tests between this type of equipment and drifters or stopers in the rock under consideration to determine which will provide the lowest cost per cubic foot excavated. Both American and Swedish manufacturers supply this equipment. The Swedish drill is sold in a package with insert rods to assure use of a drill with a light hammer blow, well within the strength limits of the carbide, thus preventing excessive carbide failure.

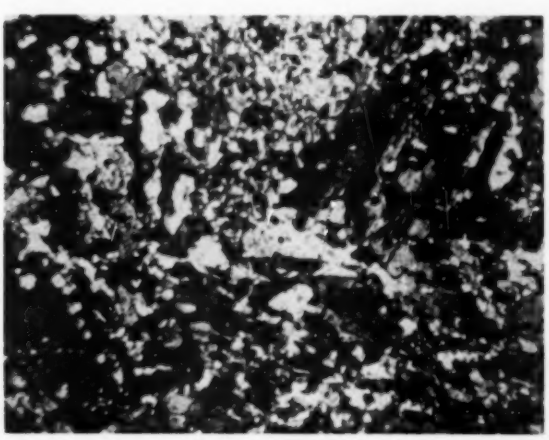
However, in view of the very definite improvement in uniformity and strength of American carbide, there is every reason to believe that the use of faster drills will be justified. Claims regarding air consumption should be based not on cubic feet of air per minute used by the machine but on the cubic feet of air per inch of hole drilled by the machine in a standard rock.

A closing plea should be made for greater standardization in describing mine rocks and their drilling characteristics. Such descriptions as *hard gneiss, hard granite, tough intrusive diabase* or *hard silicified sedimentary* leave much to be desired when an effort is made to correlate drilling results. Specifications should include description of rock drilled, drilling machine size, bit size or sizes, steel size, and average air pressure.

There appears to be a very definite lack of technical information dealing with rock properties of hardness and toughness applied to percussive drilling. An excellent article on "Rock Hardness as a Factor in Drilling Problems with Special Reference to the Petroleum Industry" appeared in the AIME Transactions, Vol. 190. Those who are interested in the physical properties of mine rocks are referred to the work of Obert, Windes, and Duval in Bureau of Mines RI No. 3891, 4459, and 4727, which list and describe properties of almost 150 individual rocks. The comparisons of impact toughness and abrasive hardness are of particular interest in a consideration of drillability with percussion equipment. The standard methods developed by Obert, Windes, and Duval give physical property data that is specific. A study of thin sections appears to explain why the impact toughness is high or why the abrasive hardness is high or low. The following slides of thin sections demonstrate reasons for the physical properties of these rocks.

Supplement

Pure limestone is readily drillable, as wide experience has shown and as laboratory data also indicate, see Table II. Typical Darwin tactite composed of wollastonite 45 pct, diopside 35 pct, and quartz 20 pct, is shown in Fig. 14. Grains of wollastonite, the lime silicate, form in a sub-fibrous habit to make the texture like a floor mat enclosing grains of diopside and quartz. Wollastonite sheafs are most apparent in the center and upper right and account for the evidently high impact toughness of the rock. Grains of wollastonite are from 3/10 to 5/10 mm in length while the diopside and quartz grains measure only 2/100 or 3/100 mm. By comparison, Butte vein quartz grains at this magnification would have an area 25 times the area of this slide. Drill cutting samples showed no +10 mesh fragments, but from 55 to 65 pct passed the −65 mesh screen. This indicated poor penetration and chipping, but on the other hand bit wear was not as severe as in quartz rich rocks. Both granite and Darwin hornstone, which is similar to Nevada tactite, have low impact toughness, produce coarse cuttings, and drill quite rapidly, but the presence of hard minerals results in severe abrasion of carbide, as laboratory data would indicate. Fig. 15 shows Darwin hornstone composed of 45 pct quartz of grain



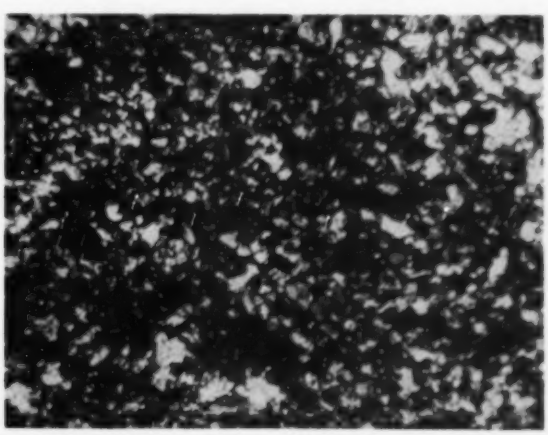
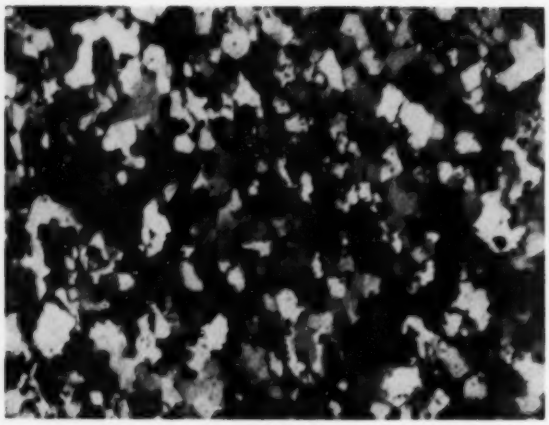


Fig. 14 (Left)—Darwin tactite, X105, and Fig. 15 (Right)—Darwin hornstone, X105.



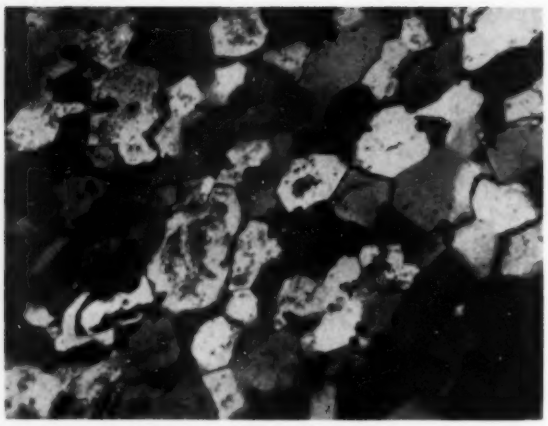


Fig. 16 (Left)—Soudan jaspilite, X105, and Fig. 17 (Right)—Swedish jasperoid, crossed nicols, X105.

size from 10 to 20 microns, 45 pct diopside with grain size from 10 to 12 microns, and 10 pct pyrite. Note that the grain boundaries are fairly uniform and not tightly interlocked. The impact toughness is not very high, drill cuttings are coarse with 20 pct +10 mesh and only 25 pct −65 mesh, and drilling speed is higher than in the tactite. However, the large percentage of fine quartz grains indicates a very high abrasive hardness, and bits are dulled in half the distance they will run in tactite.

Table II. Drillability of Various Types of Rock

Rock Type	Impact Toughness, USBM[5]	Drillability, Min	Abrasive Hardness, USBM[5]	Carbide Abrasiveness, In.	Cuttings, −65 Mesh, Pct
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Darwin tactite		10*		84	55
Nevada tactite	12.0		25		
Darwin hornstone	12.6	13*		48	25
Nevada hornstone	7.1		52		
Granite, Maryland	6.9	16**	26	48**	
Jaspilite, Soudan	17.0		48		

* 2¾-in. drill, 90 psi, ⅞-in. quarter-octagon steel, 1½-in. carbide bits.
** 3½-in. drill, 80 psi, 1¼-in. round lugged steel, 2-in. steel cross bits, Rockwell C 62.[6]

Soudan jaspilite, see Fig. 16, is well known for its low drillability, and its destructiveness to drill bits is very severe. Laboratory results from the Bureau of Mines show an extremely high impact toughness, believed to be accounted for by the sutural boundaries of the grains, which in effect lock them together as the components of a jig-saw puzzle are joined. The high abrasive hardness of jaspilite, close to that of the Darwin hornstone, is accounted for by the 96 pct fine-grained quartz composition. Charles Meyer, in charge of Anaconda's Geological Laboratory, states, "The specimen is composed of 96 pct quartz and 4 pct hematite. The grain size of both minerals ranges from 5 to 50 microns. The average semi-sutural grain shape with its high specific surface and extensive interlocking indicates high interfacial cohesion between grains."

Fig. 17 shows a thin section of a jasperoid from a Swedish iron mine. Its physical properties are unknown, but its abrasiveness to drill bits is reputed to be great. It is composed of 98 pct quartz averaging 0.10 mm in diam. Its texture suggests a lower impact toughness than the Soudan jaspilite.

The thin section shown in Fig. 18 is a jasperiod from Australian Blue Asbestos Ltd., of western Australia. It is notoriously difficult to drill. With its 98 pct quartz grains ranging from 10 to 40 microns, tightly interlocked, and with sutural boundaries similar to the Soudan jaspilite, its impact toughness and abrasive hardness are probably very high.

Further correlation of the petrographic properties, the physical properties of impact toughness and abrasive hardness, and the drillability of mine rocks should in time provide very useful data for bit selection.

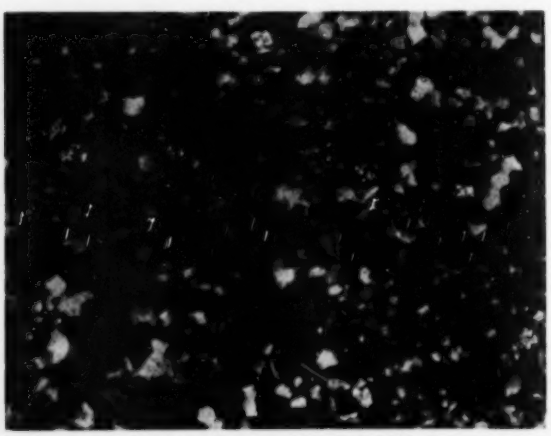

Fig. 18—Australian jasperoid. X105.

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[6] U. S. Bur. Mines *RI* 4041.

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Lewis Douglas To Address Ist Mining Branch Dinner; Gov. Thornton At Welcoming Luncheon

DAN THORNTON

Dan Thornton, colorful governor of Colorado is scheduled to address the welcoming luncheon of the AIME General Meeting to be held February 16 to 19 in Los Angeles.

Plans for the 175th General Meeting promise to produce one of the most interesting programs ever assembled in the history of the Institute. The attendance is expected to create a new record for such gatherings. Registrants will have four days of intensive technical sessions covering important aspects of mining, metallurgy and petroleum.

One of the outstanding social events on the program will be the First Annual Dinner of the Mining Branch. Lewis W. Douglas, former U. S. ambassador to the Court of St. James will address the group, it was announced by R. E. Byler, Mining Branch Chairman. Mr. Douglas is presently on the board of Mutual Life Insurance Co., a director of General Motors, Homestake Mining Co., and Newsweek magazine; national chairman of the English speaking Union of the United States, president of the Academy of Political Science, and chairman of the National Policy Board of the American Assembly. He is also a director of the New York and Southern Arizona Bank and Trust Co., International Nickel Co., and the Union Corp.

Mr. Douglas will speak informally, with Raymond Byler presiding at the dinner.

Student Participation

The Institute has made special plans for student participation. One of three meetings of the Mineral Industries Education Committee will be open to them. Following a dinner meeting at the University of Southern California, Sunday, February 16, there will be a special panel discussion on *Modern Mineral Education Curricula*.

Photo by Maria Martel

LEWIS W. DOUGLAS

Students may attend the technical sessions of all divisions; may register and receive technical papers without cost; and may attend the welcoming luncheon free. Members have been asked to sponsor students at the dinner smoker on Monday evening.

Field trip plans call for visits to aircraft factories, an automobile assembly plant, a cement plant with unique underground operations, a rock, sand, and gravel plant, a large steel mill, and local areas with unusual geological formations.

In addition to the social events already mentioned, there will be many others, including a cocktail party Monday evening at 5:30, and an informal dance Tuesday at 9 pm. The Annual Banquet takes place Wednesday evening.

Definite arrangements have been made with the Pullman Co. for lightweight, streamlined sleepers for the special train for Institute members to run between Chicago and Los Angeles. Arrangements have been made for sightseeing stopovers at Salt Lake City and Las Vegas. The train will leave Chicago at 11:55 am (CT), Friday, February 13, arriving at Salt Lake City 4 pm (MT) the next day. Arrival at Las Vegas is Sunday 9 am (PT). Arrangements were made through Union Pacific Railroad Co.

Australian Mining, Metallurgical Congress

Scientists associated with the mining and metals industries will be welcomed to the Fifth Empire Mining and Metallurgical Congress at the Inaugural session in Melbourne, Victoria, Australia, April 20, 1953.

Inspection tours covering every major mining field and metallurgical plant in Australia have been arranged. A trip to Canberra, where members will be guests of the Commonwealth Government, has also been arranged. Tours begin with a pre-session visit to Tasmania April 12 to 19, while other tours will take place simultaneously following the Melbourne sessions.

There are eight official publications of the Congress. They will comprise a series of volumes describing Australian and New Zealand geology, mining methods, metallurgical practices, ore dressing methods, extractive metallurgy, and coal.

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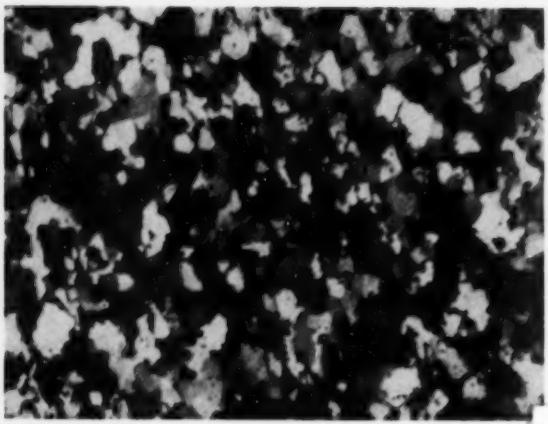

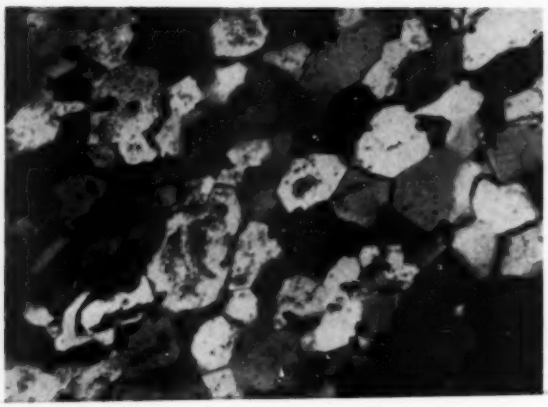

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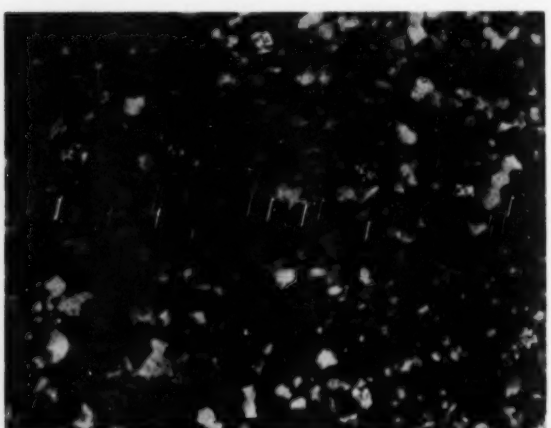

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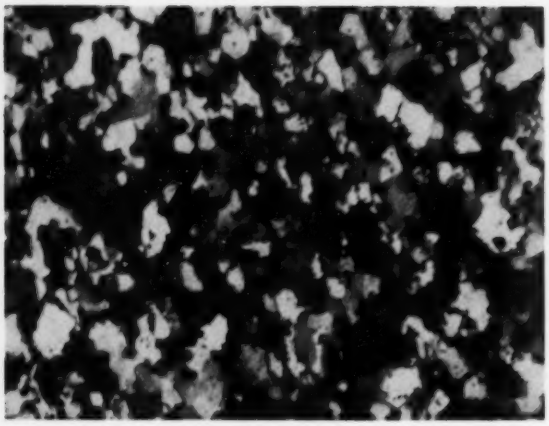

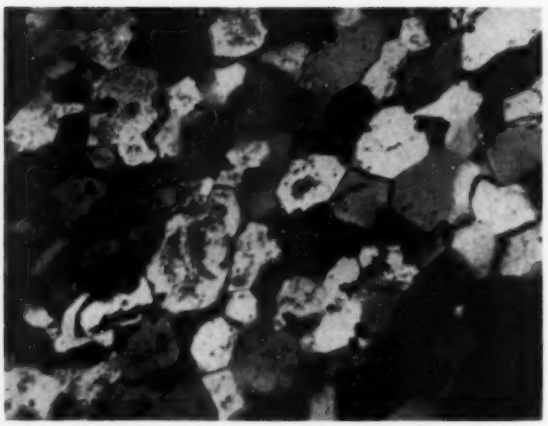

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The thin section shown in Fig. 18 is a jasperiod from Australian Blue Asbestos Ltd., of western Australia. It is notoriously difficult to drill. With its 98 pct quartz grains ranging from 10 to 40 microns, tightly interlocked, and with sutural boundaries similar to the Soudan jaspilite, its impact toughness and abrasive hardness are probably very high.

Further correlation of the petrographic properties, the physical properties of impact toughness and abrasive hardness, and the drillability of mine rocks should in time provide very useful data for bit selection.

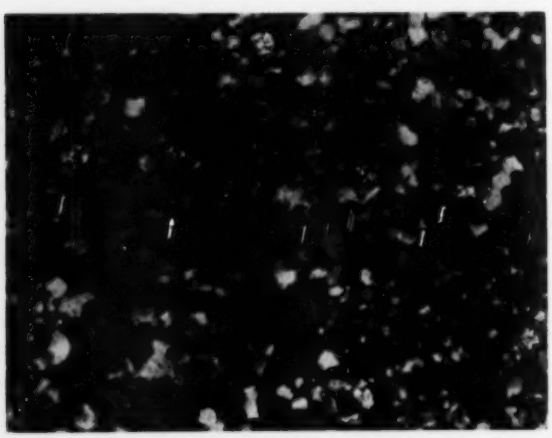

Fig. 18—Australian jasperoid. X105.

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aime NEWS

Lewis Douglas To Address Ist Mining Branch Dinner; Gov. Thornton At Welcoming Luncheon

DAN THORNTON

Dan Thornton, colorful governor of Colorado is scheduled to address the welcoming luncheon of the AIME General Meeting to be held February 16 to 19 in Los Angeles.

Plans for the 175th General Meeting promise to produce one of the most interesting programs ever assembled in the history of the Institute. The attendance is expected to create a new record for such gatherings. Registrants will have four days of intensive technical sessions covering important aspects of mining, metallurgy and petroleum.

One of the outstanding social events on the program will be the First Annual Dinner of the Mining Branch. Lewis W. Douglas, former U. S. ambassador to the Court of St. James will address the group, it was announced by R. E. Byler, Mining Branch Chairman. Mr. Douglas is presently on the board of Mutual Life Insurance Co., a director of General Motors, Homestake Mining Co., and Newsweek magazine; national chairman of the English speaking Union of the United States, president of the Academy of Political Science, and chairman of the National Policy Board of the American Assembly. He is also a director of the New York and Southern Arizona Bank and Trust Co., International Nickel Co., and the Union Corp.

Mr. Douglas will speak informally, with Raymond Byler presiding at the dinner.

Student Participation

The Institute has made special plans for student participation. One of three meetings of the Mineral Industries Education Committee will be open to them. Following a dinner meeting at the University of Southern California, Sunday, February 16, there will be a special panel discussion on *Modern Mineral Education Curricula.*

Photo by Maria Martel

LEWIS W. DOUGLAS

Students may attend the technical sessions of all divisions; may register and receive technical papers without cost; and may attend the welcoming luncheon free. Members have been asked to sponsor students at the dinner smoker on Monday evening.

Field trip plans call for visits to aircraft factories, an automobile assembly plant, a cement plant with unique underground operations, a rock, sand, and gravel plant, a large steel mill, and local areas with unusual geological formations.

In addition to the social events already mentioned, there will be many others, including a cocktail party Monday evening at 5:30, and an informal dance Tuesday at 9 pm. The Annual Banquet takes place Wednesday evening.

Definite arrangements have been made with the Pullman Co. for lightweight, streamlined sleepers for the special train for Institute members to run between Chicago and Los Angeles. Arrangements have been made for sightseeing stopovers at Salt Lake City and Las Vegas. The train will leave Chicago at 11:55 am (CT), Friday, February 13, arriving at Salt Lake City 4 pm (MT) the next day. Arrival at Las Vegas is Sunday 9 am (PT). Arrangements were made through Union Pacific Railroad Co.

Australian Mining, Metallurgical Congress

Scientists associated with the mining and metals industries will be welcomed to the Fifth Empire Mining and Metallurgical Congress at the Inaugural session in Melbourne, Victoria, Australia, April 20, 1953.

Inspection tours covering every major mining field and metallurgical plant in Australia have been arranged. A trip to Canberra, where members will be guests of the Commonwealth Government, has also been arranged. Tours begin with a pre-session visit to Tasmania April 12 to 19, while other tours will take place simultaneously following the Melbourne sessions.

There are eight official publications of the Congress. They will comprise a series of volumes describing Australian and New Zealand geology, mining methods, metallurgical practices, ore dressing methods, extractive metallurgy, and coal.

Further information can be obtained from either S. E. Sweet, C. Tennant Sons & Co., 100 Park Ave., New York City, or I. H. Carne, The Broken Hill Proprietary Co., Ltd., 100 Park Ave., New York City.

ANDREW FLETCHER

President, AIME, 1953

ANDREW (Drew) FLETCHER is a fighter. He brings to the Presidency of the AIME a record of having gone all the way with every project he has ever undertaken. Drew Fletcher stays with whatever he undertakes until the task is completed to his satisfaction. More than that, he is a man of conviction, who stands by his beliefs with a surety that only a complete grasp of the situation involved can give. But there is still more to the man who will guide the destiny of the AIME during the coming year.

Sitting in his office at 250 Park Ave., where he performs his tasks as president of St. Joseph Lead Co., one sees a simply furnished room, unadorned for the most part, and designed for working—perhaps because the man who occupies it has no time for trappings and furbishings which do not contribute to getting the job done. It is the office of a man who takes a direct line to where he wishes to go and to what he wishes done. Yet, it takes only a short time to know that Andrew Fletcher is a man of diverse interests who can talk easily and knowledgeably of many things.

The statistics are simple. Andrew Fletcher was born February 6, 1895, in New York City. He knew ships and shipbuilding before most youngsters are able to climb a ladder without falling.

"My father and grandfather were shipyard owners, here and in Scotland, and I knew that I would go into the business, too."

Before going to work, however, Mr. Fletcher went to the Hill School in Pennsylvania and then to the Sheffield Scientific School at Yale, where he graduated with a Ph.B. in mechanical engineering. But the Fletcher Shipyard in Hoboken, N. J. was still some distance away, as was St. Joe.

"I reasoned that the best way to start was to go to work for someone outside my family. That way, my father would never find out how little I really knew when I finished school. When I went to work at the Fletcher Shipyards, I wanted to be able to hold my own."

Mr. Fletcher went to work as a mechanic for Harlan & Hollingsworth, Wilmington, Del., shipyard. Mr. Fletcher remembers it as a hard school, with lessons well learned. Memories of ships and the building of them remain in the few pictures that adorn the walls of his office. Photographs of some of America's famous ships are hung about the room.

He takes a deep pride in the fact that once almost all the river boats on the Hudson River were built by his family. But it has been many years since Andrew Fletcher said goodbye to shipbuilding. Before he left, however, he held the position of foreman of the Baltimore Drydock Co., Baltimore, and later as a member of his family's firm, secretary of the Fletcher Shipyard. Toward the end of his shipbuilding career, he was in complete charge of the yard. Today, he maintains contact with ships and shipbuilding through a directorship of the American-Hawaiian Steamship Co. and by association with officials of Bethlehem Steel Co. who now own the old Fletcher yard.

A trustee of St. Joseph Lead Co., since 1921, Mr. Fletcher joined the firm as vice-president and treasurer in 1929. He has been a mining man with the same devotion that previously he gave to ships. He foresees a healthy, steadily expanding American mining industry, providing that the basic truths of the American way of life once again dominate the thinking of the country.

"The United States has forged ahead of other nations because of its underlying philosophies, rather than the more obvious, immediate palliatives which arise, run out their span, and then are forgotten under the innate strength of old established American principles."

Not all the frontiers of the country have been explored, Mr. Fletcher feels.

"Great latent possibilities remain. However, if mining is to grow, the youth of America must be assured of a prosperous mining industry. It can be the job of the AIME to present this prospect."

Mr. Fletcher predicts that the coming year will be a good one for the Institute. He feels, however, that in the past, a single man, in a single year of office, has been asked to do too much. Each of the nine AIME Presidents that he has seen, with only one year of office, was greatly handicapped. The present arrangement, which allows the Past President, the incumbent, and President-Elect to work together is a great step forward, he said.

The Industrial Hygiene Foundation of America in particular and the American Mining Congress stand as examples of improvements accomplished as a result of his association. Each organization is in a substantially better position today than when he found it.

Mr. Fletcher feels that the mining industry in general is faced with a crucial decision. It must shake off the vast network of government control which has descended upon it.

Words once spoken by Thomas Jefferson, and repeated by the president of St. Joe, may be a key to the path Mr. Fletcher's thinking follows on the place of government in the lives of men:

'If we can prevent the Government from wasting the labor of the people under the pretense of caring for them, they will be happy.'

The advice he gives to the young men he talks to is simple. "Our parents took their chances when they came to U. S. and by and large, they prospered. Our job today is to make sure the door of opportunity is held open, so that we can use our training and talents to better ourselves and our fellow men."

Mr. Fletcher has little time or patience with the so-called *liberals* who advocate compulsion in the name of progress and the better life.

"Men are more important than machines and the individual and his personality are the important things in any society which hopes to advance."

Although he has served the AIME in many ways, this is the second office he will hold as an Institute member. Mr. Fletcher was named Treasurer of the Institute upon the death of Harry Hamilton in 1944. He has change of pace, the ability to throw a hard fastball and then what baseball calls the change-up—a good thing for any man to have. To the individual in every day life, it means the ability to live fully. Among the honors Mr. Fletcher has received in recognition of his accomplishments is a doctorate from the Missouri School of Mines in June, 1949.

Aside from business, Mr. Fletcher is active in community and home, holding office as a trustee of the First Presbyterian Church, and as a member of the Planning Board of Mendham, N. J. He is modest about his golf game, but coaxing will bring forth the information that he plays in the eighties. But in late years, golf has suffered because of Mr. Fletcher's home, Three Fields—which occupies much of his free time.

His abiding interest, however, is the American worker, the man who makes the country possible—the man who makes it grow with each passing day.

Annual Meeting Social Events

Monday, February 16

Welcoming Luncheon, with Governor Dan Thornton as guest speaker.
Cocktail Party, Statler Hotel, 5:30 pm.
Smoker, in the Statler's Pacific and Sierra Rooms. Dinner and stag entertainment program.

Tuesday, February 17

Scotch Breakfast, 8 am., Minerals Beneficiation Div.
Cocktail Party, Mining Branch 6 pm., dinner, 7 pm.
Informal Dance, Embassy Room, Ambassador Hotel, 9 pm.

Wednesday, February 18

Annual Banquet, Pacific Ballroom, Statler, 7 pm., with Andrew Fletcher presented as AIME president for 1953.

Woman's Auxiliary Program

Monday, February 16

Coffee Hour, 9 am., Los Angeles Room, Statler.
Lux Radio Theater, Hollywood, 6 pm.

Tuesday, February 17

Annual Meeting, New York Room, Statler Hotel, 9:30 am.
Luncheon, at Farmers' Market, 12:30 pm.
Tour of Beverly Hills, 2 pm.

Wednesday, February 18

Round Table Discussion, Mission Room, Statler, 9:30 am.
Luncheon and Fashion Show, Crystal Room, Beverly Hills Hotel, 12:30 pm.

Changes Made In Nominating Committee

The following changes in the personnel of the Nominating Committee for AIME Officers in 1954 were made by the Executive and Finance Committees: Robert H. Ramsey in place of Francis Cameron as alternate, representing the New York Section. J. A. Morris as representative of the East Texas Section. Mr. Ramsey's address is care of *Engineering and Mining Journal*, 330 W. 42d St., New York 18, N. Y., and Mr. Morris' is P. O. Box 312, Kilgore, Texas.

Revised Who's Who

Who's Who in Engineering will soon be out in a seventh edition, the first revision since 1948. The advisory committee of Engineers Joint Council on the publication met with the editor and publisher and established minimum qualifications for inclusion in the volume.

Minimum qualifications are:

At least 10 years active engineering practice, five years of which have been in responsible charge of important engineering work.

Teachers of engineering subjects in schools and colleges of accepted standing who have taught for at least 10 years, at least five of which have been in charge of a major engineering course are also qualified.

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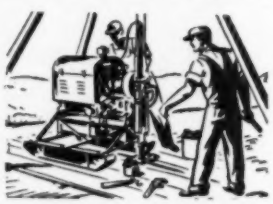

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AIME Annual Meeting Program, February 16 to 19, 1953

Statler Hotel, Los Angeles

Names of Divisions and Subdivisions are coded as follows: MIED—Mineral Industry Education Div. MED—Mineral Economics Div. M—Mining Subdiv. G—Geology Subdiv. Geophys—Geophysics Subdiv. NM—(nonmetallics) Industrial Minerals Div. Coal—Coal Div. MBD—Minerals Beneficiation Div. EMD—Extractive Metallurgy Div. IMD—Institute of Metals Div. ISD—Iron & Steel Div. Petroleum Branch—Named as such. SEG—Society of Economic Geologists.

All technical sessions and other features of the annual meeting will be held in the Hotel Statler unless otherwise specified.

SATURDAY, FEBRUARY 14

10 am to 5 pm
Council of Section Delegates

SUNDAY, FEBRUARY 15

12 m
Student Relations Committee—Luncheon

2 pm
Board of Directors

2:30 pm
MIED—At Univ. So. Calif.

7:30 pm
MIED—At Univ. So. Calif.

MONDAY, FEBRUARY 16

8:30 am
Registration

9 am
ISD—*Blast Furnace*
Petroleum Branch—Executive Committee

9:30 am
Metals Branch Council

9:45 am to 12 m
MIED
M—*Special Mining Problems*
NM—*Chemical Raw Materials*
Coal—*Mining Western Coals*
SEG—*Mineral Deposits of Southwest*

10 am
SEG Council

10:30 am
EMD—*Copper*
MBD—Business Meeting

12:15 pm
Welcoming Luncheon
Governor Dan Thornton, Speaker

2 pm
SEG, NM—*Dimension Stone*

2:30 pm
MED—*The Paley Report*
M—*New Mining Developments*
G, Geophys—*General Session*—Mayfair Hotel
NM—*Chemical Raw Materials*
Coal—*Preparation*
MBD—*Crushing and Grinding*
Petroleum Branch—*Production Review*
ISD, EMD—*Slags, Mattes, Etc.*
EMD—*Copper*
EMD—*Lead and Zinc*

Mining Branch Council

2:45 pm
SEG—*Mineral Deposits of Southwest*

5:30 pm
Pre-Smoker Cocktail Party

7:30 pm
Dinner-Smoker

TUESDAY, FEBRUARY 17

8 am
EMD—Executive Committee
MBD—Scotch Breakfast

9 am to 10:30 am
ISD, EMD—*Slags, Mattes, Etc.*

9 am to 11:30 am
MED, EMD—*Aluminum, Magnesium*

9 am to 12 m
M—*Cost Cutting Developments*
G—*Application of Geology*, Biltmore Hotel
NM, SEG—*Rare Minerals*, Mayfair Hotel
Coal—*Utilization and Preparation*
EMD—*Lead, Zinc, Antimony*
Student Session, Edison Auditorium
Petroleum Branch—*Technical Session*

9:15 am
MBD—*Materials Handling*
MBD, EMD—*Solids-Fluids Separation*

9:30 am
Women's Auxiliary Annual Meeting

10 am to 11:30 am
MGG—Executive Committee

10:45 am
ISD—Annual Business Meeting

11 am
Howe Memorial Lecture
by Joseph Winlock

12:15 pm
MGG—Luncheon—Mayfair Hotel
Coal—Luncheon
MIED—Luncheon
EMD—Physical Chemistry Committee Luncheon
Mining & Metallurgical Society of America—Luncheon

2 pm
M—*Stratified Mining*
G—*Lead, Zinc, Uranium Deposits*
NM—*Mineral Aggregates*
MBD, EMD—*Selection of Metallurgists*
MBD—*Solids-Fluids Separation*
Coal—*Mining, Handling Materials, Ventilation*
Petroleum Branch—*Valuation of Oil and Gas Properties*
ISD, EMD—*Round Table—Slags, Mattes, Etc.*
EMD—*Aluminum*

2:30 pm
NM—*Ceramic Materials*
MED—Mayfair Hotel

4 pm
Annual Institute Business Meeting

5 pm
Directors Meeting, Executive

7 pm
Metals Branch—Dinner
Petroleum Branch—Dinner
Mining Branch—Dinner
SEG—Dinner, Mayfair Hotel

9 pm
Informal Dance, AIME

WEDNESDAY, FEBRUARY 18

8 am
AIME Membership Committee
ISD—Executive Committee

9 am to 10:30 am
ISD—*Gases in Steel*

9 am to 12 m
M—*Iron Mining*
G, Eng. Geol. Div., GSA—*Engineering Geology*, Mayfair Hotel
Geophys—*Aerogeophysics*
NM—*Mining Geology*
MBD—*Concentration*
Coal—*Mine Safety*
EMD—*Physical Chemistry*
EMD—*Copper Smelting*
EMD—*Titanium and Uncommon Metals*

9:30 am
Women's Auxiliary Round Table

Petroleum Branch—*Technical Session*

11 am
IMD Annual Lecture
by Kent R. Van Horn

12:15 pm
EMD—Luncheon
NM—Luncheon

1:30 to 5 pm
Petroleum Branch—*Technical Session*

2 pm
M—*Shaft Sinking Symposium*
G—*General Session*
Geophys—*Aerogyphics: Ground Geophysics*, Mayfair Hotel
NM, MBD—*Milling Methods*
MBD—*Operating Control*
MBD—*Flotation Theory*
Coal—*Mining*
ISD—*Steel Production*
EMD—*Copper Smelting*
EMD—*Titanium and Uncommon Metals*

3 pm
AIME Nominating Committee

4:30 pm
NM—Executive Committee

7 pm
Annual Banquet
President's Reception

THURSDAY, FEBRUARY 19

9 am to 12 m
M, G
NM—*Industrial Minerals*
Geophys—*Geochemical Exploration*
MBD—*Mill Design and Construction*
SEG—*Origin of Ore-Forming Fluids*

10 am
Endowment Funds Committee

12:15 pm
MBD—Luncheon
Committee on Honorary Memberships Luncheon

2 pm
G, NM—*Nonmetallic Deposits*
Geophys—*Geochemical Exploration*
MBD—*Cleanup Session*
SEG—*Cleanup Session*

The Greenbrier Hotel at White Sulphur Springs, W. Va., was the scene of the Fall Meeting of the Central Appalachian Section of the AIME and the West Virginia Coal Mining Institute. Members were able to take advantage of wonderful golfing facilities at the hotel because of careful technical session planning.

Central Appalachian Section Joins W. Va. Coal Mining Inst. in Fall Meeting

With the famous Greenbrier Hotel at White Sulphur Springs, W. Va. as the setting, Central Appalachian Section, AIME and the West Virginia Coal Mining Institute held the Fall Meeting on Nov. 14 to 15, 1952. Including ladies, 176 registrants participated in the social and technical programs, all of which were well-planned and organized for maximum pleasure and enlightenment. Afternoons of the meeting days were left open so members could take advantage of golfing facilities available at the hotel.

Technical sessions provided five important papers for study and discussion: *Dry Cleaning Coal, Itman Plant, Pocahontas Fuel Co.* by W. J. Skewes, Chief Engineer of the company; *Wet Cleaning at the Tralee Preparation Plant* by Percy Gillie, General Manager of Mines, Semet-Solvey Div., Allied Chemical & Dye Corp.; *Rockbursts in Coal Mines* by C. T. Holland, Head of Dept. of Mining Engineering, Virginia Polytechnic Institute; *Factors that Determine Value of Coal Properties for Investment* by Carel Robinson, Robinson & Robinson, mining engineers; and *The German Coal Planer in Operation at Helen Plant, Eastern Gas and Fuel Assoc.* by W. D. Hawley, Gen. Supt. of the company. Harry Quenon, C. R. Nailler, G. R. Higinbotham, and C. H. Hodgson were chairmen for technical gatherings.

Social functions were initiated with a well-attended luncheon in the spacious dining room of the hotel. James Trotter, president of the West Virginia Coal Institute, presiding, introduced to the group Dr. Kenneth MacFarland, Educational Consultant, General Motors Corp., a stimulating speaker who discussed the spiritual growth of man. Dr. MacFarland spoke without benefit of notes and kept the crowd spellbound for over an hour. One highlight of his talk was an opinion on the cold war. He felt, "We should stop trying to contain communism in the free world, but rather let communism contain us."

On Friday, Nov. 14 the evening was taken up with a memorable reception and dinner. Fred Prosser presided and Gordon MacVean was the toastmaster. M. L. Haider, President, AIME, and his wife were present at the head table. John D. Coleman, president of the National Society of Professional Engineers addressed the group on his view of the national mineral policy.

Many of the group stayed over until Saturday evening, enjoying an afternoon of golf and hospitality of the Old White Club.

National Coal Assoc. Education Group Meets

A regular meeting of the National Coal Association's Education Committee was held at the University of Kentucky, with Leo M. Chamberlain, University vice president speaking on *The University of Kentucky and the Coal Industry.*

Members of the faculty described courses in mining and metallurgical engineering available at the school. The following day, M. E. Speare, M. D. Cooper, and Tom Pickett made reports on their spheres of activity.

Next meeting of the Committee will be held at Lehigh University, May 15 and 16, 1953.

Gulf Coast Section

Two important meetings marked recent activities of the Gulf Coast Section, with gatherings of the group taking place at Houston, Tex.

In the first of these meetings, Herbert E. Treichler of Texas Gulf Sulphur Co., presented two films on sulphur, with a discussion period following the showing.

The M. M. Kinley Co. exhibited films dealing with oil well fire fighting at the second meeting. The films were well received by the audience.

Disband Lake Superior Mining Institute

A special meeting of the Lake Superior Mining Institute adopted resolutions to distribute the remaining cash and assets in accordance with a unanimous decision of the council to disband the organization.

The general feeling held by officers of the organization was that the Institute's original purpose and objectives had been taken over by other organizations. The last meeting of the Institute was held on the Menominee Range in 1939. World War II and its aftermath left conditions unfavorable for a gathering.

The special meeting elected R. T. Elstad president, C. Brewer secretary, and R. S. Archibald, treasurer. By a vote of 227 to 1, out of 403 members of the Institute, it was decided to distribute remaining cash assets as follows:

$3000 to the Greater University Fund, University of Minnesota, for undergraduate scholarships in the School of Mines.

$7330.82 to the Alumni Foundation of Michigan College of Mining and Technology, for the Memorial Union Fund.

A resolution was adopted for the dissolution of the Institute when the cash is distributed and items of historical interest are deposited with the Marquette County Historical Society, Marquette, Mich.

Nova Scotia Planning Committee Begins Work

Picturesque fishing schooners, masts standing against clear skies, and interesting shorelines, with white breakers marching up on the beach are among the scenic wonders of Nova Scotia.

IMD Fall Meeting Promises Great Success

Preparation for the technical program for the joint meeting of the Mining Society of Nova Scotia, the Industrial Minerals Div., AIME, and the Canadian Institute of Mining and Metallurgy set for Sept. 8 to 10, 1953, is well underway.

The Papers Committee, comprised of Sanford S. Cole, M. F. Goudge, D. F. McNeil, R. C. Stephenson, John G. Broughton, H. M. Bannerman, and C. M. Cooley, will meet February 6 on final plans for activities.

Social sessions, utilizing Nova Scotia's ocean surroundings to the fullest, are being made by the Mining Society of Nova Scotia. Fishing, swimming, and sailing, have contributed to making this *Canada's Ocean Playground.*

Nova Scotia's history is rich in the lore of the sea, and it is the sea which has made it one of the most spectacularly scenic areas in the Northern Hemisphere. Long before Columbus came to America, Europeans were harvesting fish from Nova Scotia's lush banks. Later, pirates slipped quietly in and out of its coves, either seeking a hiding place or launching a marauding campaign.

Early settlers lived off the offerings of the sea, and eventually built sailing vessels for local and foreign trade. During its shipbuilding era, Nova Scotia had more ships per capita than any other country in the world. Steam finally drove Nova Scotia's sailing ships from the seas, but the fishing industry persists. Today fishing is one of the outstanding attractions, both commercially and to those who want to tie into a *big one* for the battle of a lifetime.

Tiny villages dot the coastline, and the casual visitor suddenly finds a cluster of picturesque houses in the most unexpected places. Red and white sand beaches, tree-capped islands, and rugged headlands furnish a pattern of scenic magnificence hard to match elsewhere.

The world's highest tides, ranging from 46 to 90 ft pound the shoreline and even inland, tidal rivers at ebb become canyons of clay.

This, and much more await those attending the Fall Meeting. It will be scenic beauty, pleasant social events, and the offerings of one of the outstanding vacation spots in the world combined into what promises to be a memorable gathering in AIME history.

Legion of Honor Awards To Washington Members

Legion of Honor awards were presented to C. K. Leith and Emory T. Miller, members of the Washington, D. C. Section, at a dinner held at the Hotel 2400.

Presentation was made by guest of honor M. L. Haider, 1952 President of the AIME.

Socony-Vacuum Grant

The executive committee of the Mineral Industry Education Div. has selected James E. Cockfield, Student Associate of the AIME at Ohio State University, as the recipient of the AIME—Socony-Vacuum Scholarship for the current scholastic year. The award is $750 in cash.

Student Membership Transfer Now Automatic

To facilitate transfer of Student Associates to the grade of Junior Membership in the Institute, all present requirements as to formal application were removed by action of the Directors at the December meeting of the Executive and Finance Committees. During the past year, to effect the transfer it has been necessary for the Student Associate to make out a formal application and have it endorsed by a member. Even though this was not a formidable handicap to the change of status, many Student Associates did not take the trouble to make application and were therefore dropped from the rolls at the end of the year of graduation.

It was voted "that effective in 1953, Student Associates shall automatically become Junior Members at the end of the year in which they finish school; that they shall be so advised at an appropriate time and be billed for Junior Member dues for the following year. No formal application or endorsements shall be required. If acceptance of election is not received by March 31, the Junior Member thus elected will be dropped."

Student Associates who were required to change status by Dec. 31, 1952 do not come under the new ruling.

Members of the Arizona Section greet 1952 AIME President M. L. Haider during an informal moment at the Arizona Section meeting in Tucson. From left to right, A. P. Morris, R. F. Welch, T. G. Chapman, C. R. Kuzell, W. P. Goss, E H. Robie, M. L. Haider, P. D. I. Honeyman, R. A. Harvill, R. E. O'Brien, G. J. Duff.

Arizona Meeting Attracts 494 Registrants

Some 494 persons registered for the Arizona Section Annual Meeting held at the Pioneer Hotel, Tucson, Ariz., with M. L. Haider, 1952 president of the AIME in the role of guest of honor and featured speaker at the dinner which closed the affair.

B. S. Butler held the chair during technical sessions of the Mining Geology Div. Papers presented were:

Tentative Correlation of the Sedimentary Rocks at Cananea, Sonora, Mexico, with The Section at Bisbee, Ariz., by Roland B. Mulchay and J. Ruben Velasco.

Regional Structure and Some Ore Districts in East-Central California, by Evans B. Mayo.

Geochemical Prospecting for Copper at Ray, Ariz., by Otis M. Clarke.

At a short business meeting of the division L. K. Wilson of Tucson was named chairman for the coming year and F. M. Stephens secretary.

E. B. Conners, acting chairman, called the Underground Mining Div. to order and presented authors of technical papers.

H. F. Mills, manager of the Iron King mine of the Shattuck Denn Mining Corp., read a paper on recent changes in mining and development at Iron King, located near Humboldt.

Underground Haulage of Open Pit Ore, was presented by B. B. Whitney, assistant mine superintendent, Inspiration Consolidated Copper Co. L. B. Allen spoke on *Roof Bolting Practice in Non-Carboniferous Mines*. R. F. Kast of Ray Mines Div., Kennecott Copper Corp. discussed current rock bolting equipment.

R. C. Weed of Cananea, Sonora, Mexico was unanimously elected chairman for 1953.

Innovations in blast hole drilling practices were discussed at the Open Pit Mining Div. meeting, with John A. Lenz, Jr., New Cornelia Pit; Jack Ward and Jack Dupont, Isbell Construction Co., taking part.

Warren Smith, pit superintendent, Phelps Dodge Corp., was elected Chairman for the coming year.

Ore Dressing Div. session was an all-day affair starting with a field trip to the Rillito plant of the Arizona Portland Cement Co. Technical papers were presented during the afternoon by J. Frank Henderson, of the Dorr Co.; J. K. Sellers, Copper Queen Branch of the Phelps Dodge Corp.; F. T. Davis, Magma Copper Co.; P. V. Brough, and K. B. Gillaspie, U. S. Smelting Refining & Mining Co.

Harold J. Rex, Magma Copper, was elected chairman for 1953.

F. R. Rickard, elected secretary for the year, presented two papers, one of which was prepared by Leanard Klein and the other by Mr. Rickard. J. W. Byrkit was elected 1953 chairman.

Wesley P. Goss was introduced as chairman for 1953 at the dinner. Lyle M. Barker and John A. Richards were named First and Second Vice-Chairman, and John F. Buchanan, Secretary-Treasurer.

Directors of the Section are A. T. Barr, T. G. Chapman, B. R. Coil, E. R. Dickie, G. J. Duff, D. Gardner.

Adam to Atom

The pageant, "Adam to Atom," which thousands witnessed at the Museum of Science and Industry during the Centennial of Engineering at Chicago last September, was subsequently recorded on motion picture film. Prints are available from Ideal Pictures Corp., 233 W. 42d St., New York, N. Y. Distribution will be free to schools, luncheon groups, technical societies, and to any other responsible groups, by application to Ideal Pictures.

Mining & Geophysics Fall Meeting

International Mining Days

El Paso, Texas

October 28 to 31, 1953

Ceremonies marked the inauguration of the Lima, Peru local section, with many of the AIME members in Peru attending. Fernando C. Fuchs, legion of honor member, on the left, is permanent honorary chairman. Carl W. Westphal, center, is chairman, while Ernesto A. Baertl is serving as vice chairman. Walter E. King is secretary-treasurer.

Lima, Peru Section Holds Regular Meetings

The Lima, Peru Section, latest foreign addition to the AIME, has been rolling in high gear, with attendance at regular meetings at a constantly good rate since their charter was issued.

Discussing a *Significant Program for South America*, at the latest meeting of the group, was Minister Claude W. Courand, of the U. S. Embassy, and director of Region No. 2, (South America, excluding the Guianas) Defense Materials Procurement Agency.

Also attending the luncheon meeting held at the Hotel Bolivar was Harold Tittman, U. S. Ambassador to Peru.

San Juan Subsection Holds Winter Meeting

The annual Winter Meeting of the San Juan Subsection, Colorado, was held at Montrose with a large crowd attending the gathering.

First on the list of activities was a tour of the new power plant of the Western Colorado Power Co. Registration followed by the conference was held at the Western Colorado Power Auditorium.

C. A. Rasor, production div., AEC, spoke to the registrants on geology of the uranium deposits of the Colorado Plateau. Abraham Rosehzweig, exploration div., AEC discussed the occurrence of uraninite in the sediments of the Colorado Plateau. Leo Miller, AEC exploration div., reported on the geology of the Happy Jack mine, San Juan County, Utah. An illustrated talk on new developments in exploratory drilling for uranium ores was presented by Ray Sullivan, Minerals Engineering Co.

A cocktail party was held at Moose Hall, with dinner at Community Club House in Lion Park. The dance was also held at Moose Hall.

Minnesota Section Holds Annual Meeting

About 350 persons, representing mining and mineral dressing in the Lake Superior region, Canada and several areas in the U. S. attended the 26th Annual Meeting of the Minnesota Section, at Duluth.

Mild weather contributed to making attendance at the meeting near-record, in contrast to last year's meeting held during the worst snow storm in the area in 1952. Technical sessions were held in the General Science Building auditorium of the University of Minnesota. Hotel Duluth was meeting headquarters.

Hugh J. Leach, chairman of the Section for the past year, opened the sessions. Reports were made by James R. Stuart, Section Secretary-Treasurer; A. W. Kangas, Mining Subsection Chairman, and S. E. Erickson, Minerals Beneficiation Subsection Chairman.

Warren S. Moore, program chairman, presided over the morning technical sessions. Papers were presented W. D. C. MacKenzie, Calgary, Alberta, and G. W. Smith, geologist with the consulting firm of Smith and Sessions, Bismark, N. D.

During the luncheon held at the Hotel Duluth, Herbert Heaton, professor of economic history at the main campus of the University of Minnesota spoke on the history of the mining industry.

Oliver C. Ralston, chief metallurgist with U. S. Bureau of Mines, surveyed the manganese situation at the afternoon session. He concluded that the manganese deposits of the Cuyuna Iron Range of Minnesota and manganese in open hearth slag would be the chief sources for the U. S. during an emergency.

An interim report on Allis-Chalmers Mfg. Co. efforts in heat hardening of taconite pellets was made by G. V. Woody, processing machinery division. He described the Milwaukee plant for hardening pellets and reported highly satisfactory results.

Phillip L. Merritt, geologist with the Atomic Energy Commission gave the final report of the session. He reported on AEC work along the lines of raw materials.

Earl C. Herkenhoff, secretary of the Minerals Beneficiation Subsection, made a joint committee report regarding plans for meeting to be held on the Mesabi Range this summer. Possibility of the MBD and Mining Geology and Geophysics Div. of the AIME also holding annual meetings on the Range at the same time was discussed.

Lloyd J. Severson was named chairman succeeding Mr. Leach. John L. McEachin, Eugene Pflieder, and Fred J. DeVaney were named Vice Chairmen. Secretary-Treasurer will be Everett L. Joppa.

To Hold Second Northwest Conference

The Second Pacific Northwest Metals & Minerals Conference will be held in Seattle, Wash., on Thursday, Friday, and Saturday, May 14 to 16, 1953. All events will be held at the Benjamin Franklin Hotel. Plant visits will be held Thursday afternoon, technical sessions on Friday and Saturday, and the climax will be a banquet on Saturday evening. A series of events will also be planned by the WAAIME. General Chairman for the Conference is G. A. Waterman, with J. G. Johnston as Metals Chairman, and Sheldon Glover as Industrial Minerals Chairman.

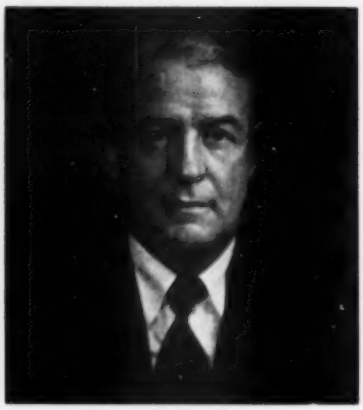
The Iron & Steel Div. session will cover electric furnace operations. Emphasis will be on various relatively new or novel procedures that have resulted in improved quality, reduction in melting time, or reduction in material cost.

Extractive Metallurgy Div. will present a series of interesting papers including one on *Modern Safety Methods in Nonferrous Smelters.*

A number of interesting papers reporting on recent research problems in physical metallurgy will be presented in Institute of Metals Div. sessions.

Personals

ALLEN H. ENGELHARDT



A. RUSSELL MERZ

A. Russell Merz and **Allen H. Engelhardt** have been appointed vice presidents of Cerro de Pasco Corp. Mr. Merz will assume charge of the company's sales and purchases at its main offices in New York. Mr. Engelhardt will continue to manage the company's metal mining, smelting and refining operations in Peru, with headquarters at La Oroya.

Roger O. Oscarson, former secretary of the Northwest Mining Assn., has been appointed minerals economist with the Bureau of Land Management's Div. of Minerals.

W. S. Phillips has been appointed mine superintendent, at the Chelan Div. of the Howe Sound Co., Holden, Wash.

Alvin H. Ross has been appointed as assistant to the vice president and general manager of the Climax Uranium Co.

Howard F. Keller, chief of the Base Metals Div. of the Defense Minerals Exploration Administration, Washington, D. C., has resigned to become general superintendent of the Naica Unit of the Fresnillo Co., at Naica, Chihuahua, Mexico.

John P. McKee has resigned his position as assistant chief geologist of the Jones & Laughlin Steel Corp. Mr. McKee is now associated with R. G. Comer in an independent exploration venture. Mr. Comer was formerly superintendent of the Vicar mine, Gogebic Range, Mich.

L. W. Allen has resigned as assistant manager of Nchanga Consolidated Copper Mines Ltd., and has been made manager of Rhokana Corp., Ltd.

A. F. Banfield, Dr. Roland D. Parks, of Behre Dolbear & Co. and **Dr. Elwood Moore** have been doing professional work at Cobalt, Ontario. **Parke A. Hodges** and **Ross Field** of the same company are making a mine examination in Sonora, Mexico.

S. M. Cassidy, who has been president of the Consolidation Coal Co. of Kentucky, has gone to Pittsburgh as a vice president of the Pittsburgh Consolidation Coal Co.

J. E. Ruykendall formerly employed by the Vulcan Mines Co. at Liclio, Peru as mine superintendent is now employed by the Gardner-Denver Co. at Denver.

H. A. Steane has accepted an appointment with Canadian Exploration Ltd. at Salmo, B. C.

R. D. Van Zante, superintendent at Rifle for U. S. Vanadium Co., has succeeded **J. E. Hopkins,** transferred to Grand Junction, as superintendent of the Uravan, Colorado mill. **H. C. Peterson** is now superintendent at the Rifle mill.

Lendall P. Warriner, former president and general manager of Appalachian Minerals Co., Monticello, Ga., has joined Cyprus Mines organization as exploration engineer in the New York office.

Clark L. Wilson is in Salt Lake City office of New Park Mining Co. Mr. Wilson was elected to the chairmanship of the Utah Section, AIME.

F. V. Hicks has been appointed general superintendent, Coal Mines & Quarries Div., of the U. S. Steel Co. The Geneva Coal Mine, the Columbia Mine, and Keiigley Quarry were consolidated into this.

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WILLIAM C. CHASE

William C. Chase, formerly general superintendent of mines of the Alabama By-Products Corp., has been promoted to executive assistant and general mining consultant. **Henry J. Hager,** formerly assistant general superintendent of mines, was made general superintendent of mines.

J. D. Crawford has been elected vice president and general manager of Alaskan operations of United States, Smelting, Refining, & Mining Co., and **C. G. Rice** vice president and general manager of oil operations.

Frank M. Estes has returned to his home in Memphis, Tenn., after a six months' professional trip to Colombia, S. A.

R. H. Feierabend and **C. M. Sampson** have been appointed general superintendents of operating properties of Freeport Sulphur Co. in Louisiana. Mr. Sampson will be responsible for the operations of Garden Island Bay and Bay Ste. Elaine. Mr. Feierabend will be responsible for Grande Ecaille operations. **J. E. Monroe** has been appointed to the position of superintendent of production at Grande Ecaille. **W. S. Donner** has been appointed superintendent of Bay Ste. Elaine.

Cecil Fitch, Jr., vice president and general manager, Chief Consolidated Mining Co., Eureka, Utah, was elected president of the Utah Mining Assn. at the annual meeting of the Board of Directors. **J. Parnell Caulfield,** assistant to the general manager, western mining divisions, Kennecott Copper Corp., was advanced from second to first vice president of the association. **Otto Herres,** vice president of the Combined Metals Reduction Co. was elected second vice president.

John J. Grady is now vice president and general manager of Chromium Mining & Smelting Corp.

W. E. Hess has been appointed manager of coal mines for Jones & Laughlin Steel Corp. Formerly general superintendent of coal mines, Mr. Hess will be responsible for operation of the Vesta-Shannopin Coal Div., California, Pa., and the Twin Branch-Black Eagle Coal Div., Twin Branch, W. Va.

Robert S. Sanford has recently returned to Washington, D. C. after spending 26 months in South Asia. He was on loan from the U. S. Bureau of Mines, first to the Department of State, and later to the Technical Cooperation Administration. Mr. Sanford advised the government of Afghanistan for a year and in Nepal he examined mineral deposits never before visited by any westerner.

Richard W. Flagg has joined the research dept. of Dorr Co., Westport, Conn. Mr. Flagg took his degree in metallurgy from the University of Arizona and has been employed in the research laboratory of the Miami Copper Co., Miami, Ariz.

William B. Kempton has been appointed as sales manager of the Hardware Products Dept. of the Wickwire Spencer Steel Div. of the Colorado Fuel & Iron Corp. Prior to his joining CF&I as a salesman in their New England District sales office, he was associated with the United States Steel Corp.

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GEOLOGICAL INVESTIGATIONS

Obituaries

George M. Brown (Member 1949) has died. Mr. Brown had extensive experience in the mining field and his main technical interest was metal mining. From 1946 to 1948 he was assistant general superintendent and general superintendent for Tungsten Mining Corp. He was employed by the Haile Mines, Inc., first as field engineer in charge of plant design and construction and then as superintendent of Tungsten Div. Some of his earlier positions were with the Colorado Iron Works Co., where he was manager of their New York office and with Arizona Middlemarch Copper Co., in Pearce, Ariz. Born in Summit County, Ohio, he attended Arizona State Teacher's College in Tempe, Ariz.

Robert Gale, Jr. (Member 1947) died September 6, 1952. Mr. Gale worked for the Anaconda Copper Mining Co. for a number of years. He started as a miner, became mine sampler, assistant mining engineer and then mining engineer for this company. His major technical interests were metal mining and mining geology.

Otto D. Rohlfs, Sr. (Member 1937) died September 25, 1952. He was a mining engineer and former city engineer and city water superintendent. Mr. Rohlfs attended the University of Washington and was a graduate of Columbia School of Mines and of the Freiberg School of Mines, Heidelburg University, Germany. He engaged in mining in Alaska, California and the Orient; taught mining at the University of Washington for a year, and during World War II served as principal engineer for the War Production Board Minerals Division, Washington, D. C. Recently he was employed in the engineering dept. at Boeing Airplane Co.

Lafayette G. Johnson (Member 1917) died November 16, 1952. Mr. Johnson was born in Silverton, Colo., and educated at the Colorado School of Mines. He held positions with Portland Gold Mining Co. and the Federal Lead Co.

Samuel B. Goldberg (Member 1921) died April 11, 1952. He held positions with Colorado Mining Co., in Masbate, P. I., as assistant to general manager and as mining engineer with Northern Peru Mining & Smelting Co. He had done consulting work in Idaho, Nevada and Utah. Mr. Goldberg worked as assistant superintendent for Cia Mra. Nazareno Y Catasillas, Salaverna, Zac., Mexico. Educated at University of Minnesota and University of Arizona, he received an E.M. and Ad. E.M. degree. Mr. Goldberg had a wide and varied career in the mining industry and had worked for many well-known mining companies.

Jerome B. Grigg (Member 1943) died October 4, 1952. Mr. Grigg, whose main technical interest was in the mining, preparation and utilization of coal, had worked for Carbocoal Corp., and Sangamon County Coal Mining Co. as foreman. He was also employed by M. A. Hanna Co. as combustion engineer. Born in Mt. Holly, N. J., he was educated at University of Illinois.

Appreciation of
Earle William Berry
By W. F. Boericke

Earle William Berry died in San Francisco November 23, 1952 in the Marine Hospital after a prolonged illness. Mr. Berry was well known in mining circles and had done extensive professional work in California, Nevada, New Mexico and the Philippine Islands, where he was associated with Benguet Consolidated. He left the Philippines before the war and was mechanical superintendent for Kennecott Copper's Ruth mine in Nevada. In 1950, he went to Turkey as mill superintendent for the Turkish Government at their Guleman Chrome mine. Later he did professional work in Guatemala and

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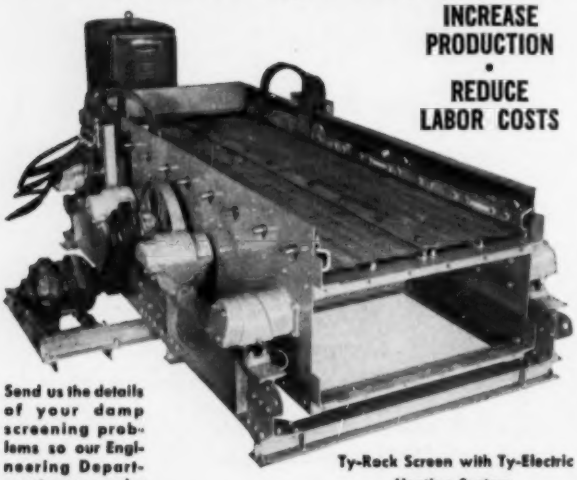

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subsequently he spent a year as mechanical superintendent for Basic Refractories in Nevada.

No one who knew Earle Berry failed to be impressed with his abundant energy and courage. He welcomed opportunity to develop a new enterprise under the most difficult mining conditions. He was responsible when I knew him for bringing the Batong-Buhay Mine into production in one of the most remote areas in Mount Province in the Philippine Islands. He was a loyal friend and his early death will be grieved by all his associates. He leaves a wife and a daughter who are located in California.

Appreciation of
McHenry Mosier
By W. T. Millar

McHenry Mosier (Member 1936) succumbed to a heart attack on October 19, 1952 at the Suburban Hospital, Bethesda, Md.

Born in Des Moines, Iowa, March 27, 1885, and a graduate of Iowa State College, Ames, Iowa, majoring in mining engineering and geology, Mr. Mosier began his mining career in the southwest. He worked his way up in private industry to superintendent of mines for the Phelps Dodge Corp. in Arizona. He also served as geologist and examining engineer for that company and later went into private practice as consulting engineer.

McHENRY MOSIER

Mac, as most of his friends knew him, had a broad experience in mining throughout the United States and Mexico. In September 1935 he became affiliated with the U. S. Bureau of Mines. During this affiliation he had various assignments in conducting and directing research in mining practices. At the outbreak of World War II he was appointed chief of the Copper Branch for the Bureau of Mines with offices in Washington, D. C. After a reorganization of the Bureau which occurred near the end of the war, Mr. Mosier was appointed chief of the Mining Development Branch for Region VIII with headquarters at College Park, Md. in which capacity he served until death.

Mr. Mosier contributed much to the solution of technical problems and is the author of numerous technical publications.

He was a man of absolute integrity and sincerity which gained him respect and many friends.

Mr. James A. Ross, president of Sprague & Henwood, Inc. said of him "There wasn't any fellow who thought as much of his friends and associates as Mr. Mosier."

He is survived by his wife, formerly Louise Alta Laurence of Cedar Rapids, Iowa; two daughters in California, and one son, Dr. Laurence Mosier, now a surgeon with the U. S. Air Force in Morocco.

NECROLOGY

Date Elected	Name	Date of Death
1951	T. W. Anderson	Unknown
1935	C. H. Bliem	Unknown
1923	John L. Bray	Dec. 6, 1952
1917	Tempie G. Bridgman	Nov. 25, 1952
1945	John Clarkson	June 11, 1952
1907	Glenville A. Collins	Nov. 12, 1952
1921	Frank L. Estep	Dec. 11, 1952
1949	Henry F. Forbes	Sept. 20, 1952
1940	L. E. Hanley	Nov. 15, 1952
1926	H. M. Hartmann	Aug. 17, 1952
1914	William F. Lewis	July 12, 1952
1938	M. B. Lovelace	Apr. 11, 1952
1946	Samuel S. Marshall, Jr.	Dec. 8, 1952
1921	Allan M. McDermott	Unknown
1942	Frederick R. Mitchell	Apr. 28, 1952
1948	O. C. Schmedeman	Dec. 1951
1940	Vivian P. Strange	Apr. 14, 1952
1949	Kolagotla B. Swamy	Dec. 3, 1952
1942	Whitman Symmes	Unknown
1904	R. P. Wheelock	Nov. 17, 1952
1917	William Ryer Wright	Nov. 26, 1952

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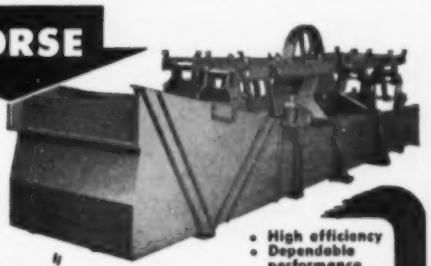

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ADMISSIONS COMMITTEE

T. D. Jones, Chairman; Thomas G. Moore, Vice-Chairman; H. S. Bell, F. W. Hanson, R. H. Chadwick, T. W. Nelson, C. A. R. Lambly, John T. Sherman, A. C. Brinker, G. P. Lutjen, Ivan Given, E. A. Prentis, C. Leslie Rice, Jr., and J. H. Scaff.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

Arizona
Ajo—Burns, Bartholomew J. (C/S—S-J)
Globe—Fletcher, James B. (R. M)
Miami—Henderson, Thomas D. (R. M)
Patagonia—Simon, Paul I. (C/S—S-J)
Phoenix—Waters, George D. (A)
Tucson—Hillebrand, James R. (J)

California
Idria—Gerling, Robert W. (J)
Oakland—Pruden, Worrell F. (M)

Colorado
Denver—Hawkes, Herbert E., Jr. (R. M)
Pueblo—Erickson, Reed G. (C/S—S-J)

Idaho
Kellogg—Park, Morey A. (R. M)

Illinois
Flossmoor—Davidson, David E. (M)

Massachusetts
Winchester—Cole, James W. (C/S—S-J)

Michigan
Calumet—Messner, D. James (C/S—S-J)
Ottawa Lake—Hingst, John M. (C/S—S-J)

Minnesota
Chisholm—Giavelli, Martin T. (C/S—S-J)
Coleraine—Unger, Harold F. (C/S—S-J)
Coleraine—Vik, Richard A. (C/S—S-J)
Virginia—Mohr, Thomas C. (C/S—S-J)

Missouri
St. Louis—Wilson, Glenn E. (J)

Montana
Butte—Brady, George T. (A)
Butte—Jaccar, Michael G. (J)
Butte—McAleer, Joseph F. (C/S—S-J)

New Jersey
Rockaway—Keenan, Alan F., Jr. (C/S—S-J)

New Mexico
Bayard—Barnes, Robert A. (C/S—S-J)

New York
Huntington—Lutjen, George P. (C/S—J-M)
Middletown—Pachett, Joseph E. (C/S—S-J)
New York—Audollent, Jean M. (J)

North Carolina
Burlington—Terry, James H. (C/S—S-J)

Ohio
Dayton—Brashear, Eugene (C/S—S-J)

Pennsylvania
Carnegie—Brisse, A. H. (M)
Easton—Farrell, J. Cottrell (M)
Norristown—Witmer, Benjamin F. (M)
Philadelphia—Green, Michael E. (C/S—S-J)
Pittsburgh—Drisko, John W. (A)
Springtown—Aiken, Robert E. (A)

Texas
El Paso—Curtan, Cornelius R. (A)
El Paso—Horton, H. Bernard (M)
El Paso—Hurxthal, William E. (M)
San Antonio—Kurz, Joseph H. (C/S—S-J)

Virginia
Arlington—Thomson, Robert D. (J)
Arlington—Walker, Walter B. G. (J)

West Virginia
Wheeling—Gondonneau, Pablo (M)

Alaska
College—Patten, Lowell L. (C/S—S-J)

(Continued on page 224)

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Coming Events

Feb. 4, AIME, Chicago Section, Chicago Bar Assn., Chicago.

Feb. 12-14, Colorado Mining Association Meeting, Denver.

Feb. 16-19, AIME, annual meeting, Statler Hotel, Los Angeles.

Mar. 8-11, American Institute of Chemical Engineers, Buena Vista Hotel, Biloxi, Miss.

Mar. 11, AIME, Connecticut Section, Brass Mill Clinic, Waterbury, Conn.

Mar. 16-20, National Assn. of Corrosion Engineers, annual conference and exhibition, Hotel Sherman, Chicago.

Mar. 23-27, ASM, Western Metal Congress and Exposition, Pan-Pacific Auditorium, Los Angeles.

Apr. 12-May 23, Empire Mining and Metallurgical Congress, Australia-New Zealand.

Apr. 20-22, AIME, National Open Hearth and Blast Furnace, Coke Oven and Raw Materials Conference, Hotel Statler, Buffalo.

Apr. 25-May 10, Fifth Liege International Fair, Liege, Belgium.

May 11-14, American Mining Congress Coal Convention & Exposition, Public Auditorium, Cleveland.

May 14-16, Pacific-Northwest Metals and Minerals Conference of 1953, joint meeting of Metals Branch and Industrial Minerals Div., Ben Franklin Hotel, Seattle.

May 14-23, Thirtieth Anniversary International Petroleum Exposition, Tulsa.

May 18-22, Fifth National Materials Handling Exposition, Convention Hall, Philadelphia.

June 3-7, Chemical Institute of Canada, Windsor, Ont.

June 16-19, Materials Conference held concurrently with First Exposition of Basic Materials, Hotel Roosevelt, New York.

Sept. 8-12, Joint Meeting Industrial Minerals Division, AIME, Keltic Lodge, Ingonish, Nova Scotia.

Sept. 21-23, American Mining Congress Mineral Mining Convention, Olympic Hotel, Seattle.

Oct. 19-21, Institute of Metals Division, Fall Meeting, Hotel Allerton, Cleveland.

Oct. 28-31, AIME, El Paso Meeting, in cooperation with International Mining Days, Paso Del Norte, El Paso.

Oct. 29-30, AIME, ASME Fuels Conference, Conrad Hilton Hotel, Chicago.

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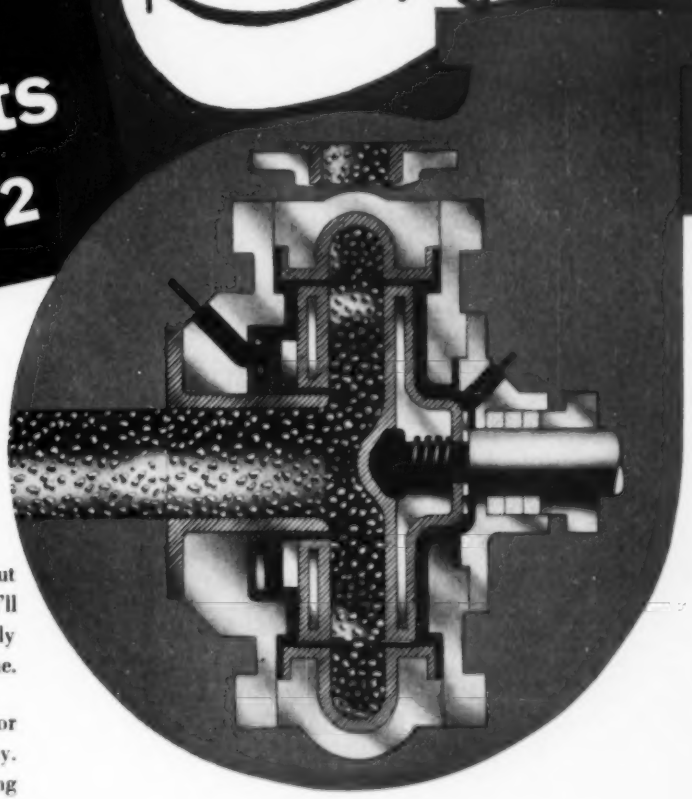

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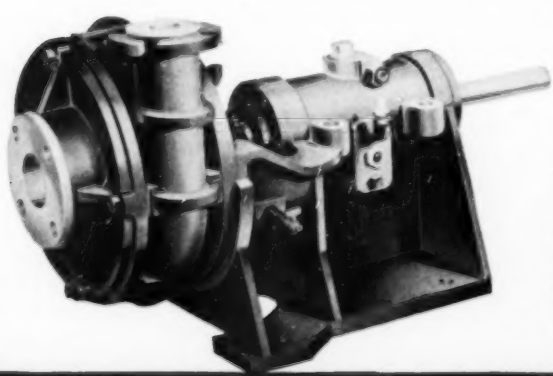

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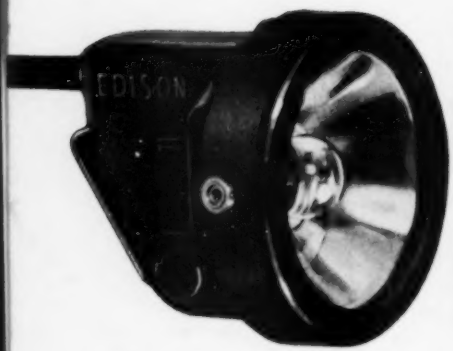

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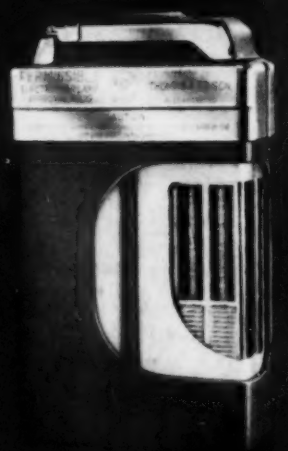

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